ACID RAIN

HEARING

BEFORE THE

COMMITTEE ON
ENVIRONMENT AND PUBLIC WORKS
UNITED STATES SENATE

NINETY-SEVENTH CONGRESS

FIRST SESSION

ON

S. 1706

TO AMEND THE CLEAN AIR ACT TO BETTER PROTECT AGAINST INTERSTATE TRANSPORT OF POLLUTANTS, TO CONTROL EXISTING AND NEW SOURCES OF ACID DEPOSITION, AND FOR OTHER PURPOSES

S. 1709

TO AMEND THE CLEAN AIR ACT TO PROVIDE FOR A PROGRAM TO CONTROL ACID PRECIPITATION

AND

S. 1718

TO AMEND THE CLEAN AIR ACT WITH RESPECT TO INTERSTATE POLLUTION ABATEMENT

OCTOBER 29, 1981

SERIAL NO. 97-H30

Printed for the use of the Committee on Environment and Public Works

U.S. GOVERNMENT PRINTING OFFICE
87-365 O WASHINGTON : 1982

S321-14

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CONTENTS

OPENING STATEMENTS

Page

Baucus, Hon. Max, U.S. Senator from the State of Montana 7
Chafee, Hon. John H., U.S. Senator from the State of Rhode Island 4
Mitchell, Hon. George J., U.S. Senator from the State of Maine 6
Randolph, Hon. Jennings, U.S. Senator from the State of West Virginia 3
Stafford, Hon. Robert , U.S. Senator from the State of Vermont 1

WITNESSES

Arnott, Dr. Robert, assistant director, Colorado Department of Health, Denver, Colo 65
Bennett, Kathleen M., Assistant Administrator for Air, Noise, and Radiation, Environmental Protection Agency, accompanied by Paul Stolpman, Director, Office of Policy Analysis, EPA 42
  Prepared statement 274
Dodd, Hon. Christopher J., U.S. Senator from the State of Connecticut 24
  Prepared statement 87
Durenberger, Hon. Dave, U.S. Senator from the State of Minnesota 16
Farrand, Chris, vice president, Peabody Coal Co., Washington, D.C. 71
  Prepared statement 550
Flacke, Hon. Robert, commissioner, Department of Environmental Conservation, Albany, N.Y. 55
  Prepared statement 290
Friedman, Robert M., Congressional Office of Technology Assessment 29
  Prepared statement 250
Gerstner, William C., executive vice president, Illinois Power Co., Decatur, Ill. 68
  Prepared statement 512
Hair, Jay D., Executive Vice President, National Wildlife Federation, Washington, D.C. 76
  Prepared statement 705
Hawkins, David, staff attorney, Natural Resources Defense Council, Washington, D.C. 74
  Prepared statement 698
Hinkley, William, environmental administrator, Department of Environmental Regulations, Tallahassee, Fla 61
  Prepared statement 317
Holmes, Dr. John R., chief, Research Division, California Air Resources Board, Sacramento, Calif 56
  Prepared statement 304
Martini, Robert task force leader, Department of Natural Resources, Rhinelander, Wis 63
  Prepared statement 322
Tierney, Hon. James E., attorney general, Augusta, Maine 60
  Prepared statement 312

ADDITIONAL MATERIAL

Bills, reprints of:
  S. 1706 763
  S. 1709 773
  S. 1718 783
Environmental Defense Fund, "Acid Rain and Wildlife Conservation" 737

Page
"Impact Assessment of Airborne Acidic Deposition on the Aquatic Environment of the United States and Canada," a Report of the Environmental Protection Agency 338

Statements:

Moynihan, Hon. Daniel Patrick, U.S. Senator from the State of New York.. 9
Pell, Hon. Claiborne, U.S. Senator from the State of Rhode Island 20
Weicker, Hon. Lowell P., Jr., U.S. Senator from the State of Connecticut .. 13
Brennan, Hon. Joseph E., Governor, State of Maine 119
O'Neill, Hon. William A., Governor, State of Connecticut 111
National Governors' Association 114
Ajello, Hon. Carl R., attorney general, State of Connecticut 112
Eastern States Attorneys General 127
Atmospheric Sciences Research Center 653
National Academy of Sciences 1
Sierra Club, Connecticut Chapter 109

ACID RAIN

THURSDAY, OCTOBER 29, 1981

U.S. SENATE,
COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS,
Washington, D.C.

The committee met at 9:40 a.m., in room 4200 Dirksen Senate Office Building, Hon. Robert T. Stafford, chairman, presiding.

Present: Senators Stafford, Chafee, Gorton, Randolph, Hart, Moynihan, Mitchell, and Baucus.

OPENING STATEMENT OF HON. ROBERT T. STAFFORD, U.S. SENATOR FROM THE STATE OF VERMONT

Senator STAFFORD. The meeting of the Committee on Environment and Public Works will please come to order.

For the committee we say welcome to our guests and witnesses who are here this morning. We have numbers of witnesses, so the meeting may be somewhat protracted.

The chair, for the committee, would remind the witnesses, in view of the numbers who will appear, in each case we have, in the telegram of invitation, asked witnesses to confine their oral statements to 10 minutes, summarizing their written statement, which will appear in the record in full.

Since we are extremely short on time, I am making no prepared statement as we start these hearings. However, I will take the opportunity to read into the record a short statement for the National Academy of Sciences whose witnesses were unable to be here.

As many of you know, the National Academy of Sciences has recently released a report on the effects of acid precipitation and related pollutants. The committee had asked a representative of the Academy to testify before us. D. W. Schindler has submitted a statement, and it is sufficiently important so I am going to read it.

It is entitled "Detrimental Effects of Acid Precipitation and Related Pollutants," and it bears the name of D. W. Schindler, Chairman, Committee on the Atmosphere and Biosphere, National Research Council, National Academy of Sciences.

STATEMENT OF THE NATIONAL ACADEMY OF SCIENCES

Protocol for the Recent CAB Report:

1. Acid precipitation was studied by the CAB committee as part of a larger review of both industrial and natural emissions to the atmosphere of a wide variety of pollutants, transport and transformation of the pollutants in the atmosphere, redeposited in the biosphere, and their potential for biological harm once redeposited on the earth.

2. In the process of their work, committee members reviewed research from the mid-19th century until early 1981. Committee members included prominent scien-

tists from the U.S., Canada, Norway and Sweden, with expertise on emissions, atmospheric transport and chemistry, global geochemistry, and biological effects of pollutants. Several of the committee members had had considerable research experience with the acid precipitation problem.

3. Once completed, the CAB report was formally reviewed by a panel of expert reviewers appointed by a National Academy Board, representing universities, industries and government laboratories. Numerous informal reviews by experts in relevant fields were also arranged by the CAB chairman and committee members. Criticisms of all of the above were accounted for in the final draft of the report before its approval by the Academy.

Major Findings and Recommendations of the CAB Report:

1. Fossil fuel burning is the single largest source of atmospheric pollution.

2. A number of pollutants are emitted from fossil fuel burning in quantities large enough to warrant concern on a regional, continental or global scale. These include oxides of sulfur and nitrogen; numerous toxic metals such as lead, zinc, mercury, cadmium, arsenic and selenium; carbon dioxide; and numerous organic substances which have known carcinogenic or mutagenic properties.

3. Many of the above pollutants have been shown to adversely affect the environment or its inhabitants when administered in amounts which are common over large areas at the present time. Others are projected to exceed "thresholds" in the next few decades where toxic effects have been demonstrated.

4. Many combinations of the above pollutants are known to be far more toxic when administered together than the pollutants considered singly. Examples include acid precipitation and toxic metals, ozone and oxides of sulfur and nitrogen, and oxides of nitrogen and hydrocarbons.

5. Acid precipitation is the best known and best researched environmental problem originating from fossil fuel burning. Clear evidence for increasing acidity of lakes, rivers and groundwaters has come from several studies in the U.S., Canada, Norway, Sweden, Denmark, Scotland and a number of central European countries. There is a clear evidence for deterioration of aquatic ecosystems in geologically-sensitive areas when the pH of precipitation falls below 4.7. There is no clear evidence of damage at higher pH values.

Geologically-sensitive lakes in areas where rain is more acid than pH 4.7 number in the hundreds of thousands. Largest areas include the southern halves of Norway and Sweden, the eastern third of Canada, the northeastern U.S.A., Scotland, and large areas of the Soviet Union.

6. At present, there is no clear evidence that acid precipitation damages terrestrial ecosystems or soils. Such damage is, however, expected to occur eventually, because losses of plant nutrients are occurring. On the other hand, the oxides of sulfur and nitrogen which are precursors of acid rain have been shown to severely affect forests and agricultural crops, particularly when combined with ozone. Hence, the same emissions are damaging both terrestrial and aquatic systems, although by different modes of action.

7. Acid combined with other pollutants or natural substances has greater detrimental effects than acid alone. For example, acid plus the aluminum leached from acidified soils causes fish kills at low concentrations where neither pollutant alone would be harmful. Several toxic metals have enhanced toxicity under acid conditions, including copper, lead and zinc. Mercury concentrations in aquatic food chains increase under acid conditions.

8. While the question of how recently and how rapidly the acidity of precipitation has increased has not been totally resolved, it is of secondary importance. Recent lake acidification could be the result of slow but steady addition of atmospheric acids in excess of lakes natural buffering ability for several decades. In fact, the CAB report documents clear evidence for the occurrence of acid precipitation in the industrial midlands of England in the mid-19th century.

9. Adverse effects of acidification on the organisms in lakes begin to occur at relatively high pH values. Both Scandinavian and North American studies have shown that species which are critical food organisms for fishes disappear when the pH of lakes falls below 5.8 to 6.0. The loss of sport fisheries, which is popularly regarded as evidence of acidification, occurs in the terminal stages of the acidification process, after severe and perhaps irreversible damage to the ecosystem has taken place.

10. There is great similarity in the patterns of emissions of sulfur and nitrogen oxides, in atmospheric concentrations of oxides of sulfur and nitrogen and sulfates and nitrates, and in acid precipitation. This fact, plus what is known of atmospheric transport and chemical reactions strongly link acidification damage to man-made SO_2 and 28 percent of man-made NO_x in the U.S. are emitted by electrical utilities.

Metal smelting and fuels burned in transportation are other important sources of the oxides.

Senator **Stafford**. That concludes the report of the National Academy of Sciences.

Since I have no additional opening statement than to read that into the record, Senator Randolph, we would be pleased to hear your opening statement.

OPENING STATEMENT OF HON. JENNINGS RANDOLPH, U.S. SENATOR FROM THE STATE OF WEST VIRGINIA

Senator **Randolph**. Thank you very much, Mr. Chairman and members of the committee who are with us now.

Mr. Chairman, this is the last hearing the committee will conduct before we begin meeting to consider possible amendments to the Clear Air Act.

The subject we will discuss today illustrates as well as anything I know why we must have a national approach to reducing the contamination of the air we breathe. We recognized long ago that pollution knows no boundaries established between States. It has been recently emphasized to us by our friends in Canada that national borders likewise do not impede the movement of pollutants. It is encouraging that Representatives of the United States and Canadian Governments will begin talks in Canada next week to develop an air pollution treaty as provided in a Memorandum of Intent signed last year.

I look forward to reviewing with our witnesses the proposals contained in bills introduced by Senators Moynihan, Mitchell, and Dodd in addition to the general subject of the long-range transport of pollutants.

There are two issues before us. The first is the movement of pollution on the air currents, often far from their sources. This action can often prevent distant communities from achieving their clear air goals.

The second issue deals with the transformation of some types of chemicals during their airborne journeys so that they come back to Earth as acid. Many scientific authorities blame this sequence of events for the accumulations of acid that are destroying life in many lakes and streams.

Both of these matters are relevant to West Virginia. Our concerns about receiving air pollutants from other States led me to sponsor what became section 126 of the Clean Air Act in 1977. This permits one State to take legal action against another to halt the interstate export of pollutants.

West Virginia's experience under the law is varied. Our State has both sued and been sued because of the interstate movement of air pollution.

We must also be concerned about airborne acid accumulations in our streams. The situation is illustrated in a report prepared by Don Gasper, a scientist with the West Virginia Department of Natural Resources. He has found that more than one-third of our native brook trout streams are threatened by acid depositions. Some have so much acid in the early spring that they cannot be stocked with fish.

The West Virginia University School of Forestry also is conducting studies on the decreased yield of some of our forests which is thought to be due to acid precipitation. Similar reports from throughout the country indicate that this problem is nationwide.

We must understand, however, that these are complex problems. There is some dispute in the scientific community about the extent to which airborne pollutants result in acid accumulations in distant waters. There are those who believe more research is needed, and those who believe equally strongly that action must be taken now before the problem worsens.

Much—but not all—of the problem is attributed to the burning of coal. I have long believed in the expansion of coal use as essential to our national energy policy. But I am also convinced that this can only take place if coal is used in ways that do not damage the environment. Laws to achieve both goals have been developed with this dual purpose in mind.

I believe that if we approach the question of long-range transport and acid deposition in the same manner we can reach a successful accommodation of the conflicting viewpoints. This is a crucial problem. We must not delay addressing it and I hope that we can come to the point of action in our committee in the near future.

Mr. Chairman, the witnesses we will counsel with today are knowledgeable and represent varied backgrounds. Their testimony will be helpful to us as we address these issues which are of great concern to many people.

Thank you.

Senator **Stafford**. Thank you very much, Senator Randolph.

Senator Chafee?

OPENING STATEMENT OF HON. JOHN H. CHAFEE, U.S. SENATOR FROM THE STATE OF RHODE ISLAND

Senator **Chafee**. Mr. Chairman, I have a prepared statement which I would like to include in the record to save time so we might get on with the witnesses.

I might say this, Mr. Chairman: I am a cosponsor of Senator Mitchell's bill. I believe in it. I find there are two principal points we have got to deal with. One, does the acid rain problem exist? Can we trace it? I believe we can. I think that has been scientifically proved.

And secondly, then, what do we do about it? Some people suggest the cure proposed is very expensive. Certainly it might be expensive, but I find it odd that somebody can cause an offensive act that is destructive to his neighbor and then seek refuge behind the fact that it is expensive to cure what he is doing. I don't think my neighbor should be able to throw his garbage on my lawn and say it is very expensive for him to hire a garbage man, and it is much cheaper for him to throw it on my lawn, and because of the expense problem, he should be able to continue what he is doing. Obviously no one would subscribe to that view.

If these coal-burning utilities are spewing the concentrates in the air that subsequently result in acid rain, then they ought to pay for cleaning it up. My State—I represent an Eastern State—is one of those that in the survey by the National Wildlife Federation was listed as 1 of the 15 States extremely vulnerable to the effects of acid rain. And I don't want that to happen.

We found in many ways that the environment has a tremendous capacity to revive itself, if you give it half a chance. But the proof is that acid rain has devastating and lasting effects upon our lakes, rivers, ponds, and streams.

So, Mr. Chairman, I look forward to hearing the witnesses.

I congratulate Senator Mitchell in proposing this legislation. Maybe this isn't the perfect answer, but we will move on and try to come up with it.

Thank you Mr. Chairman. I would ask my statement be included in the record.

Senator **STAFFORD**. Without objection, it will be included.

[Senator Chafee's statement follows:]

Senator **CHAFFEE**. Good morning. I am pleased that this committee is addressing one of the most complex environmental problems we are facing today—the phenomenon known as acid rain.

Acid rain results from oxides of sulfur and nitrogen reacting with water vapor in the atmosphere to produce rain and snow that have been estimated to be 20 to 40 times more acidic than natural rainfall. This acid precipitation is said to be responsible for the damage and death of many fish populations, a decrease in forest and crop growth, and even the corrosion of buildings.

The National Academy of Sciences has reported that acid rain is a "serious hazard" to human health and the environment. As a Senator from a State in the Northeast—an area which finds itself downwind from much of the air pollution generated in the Midwest—I am deeply concerned with this problem for my region, and the entire country as well.

My State of Rhode Island is 1 of 15 States that are extremely vulnerable to the harmful effects of acid rain, according to a recent study by the National Wildlife Federation. On a scale in which zero represents the most acid, the study states, Rhode Island's rainfall averages a 4.4; most fish species die at acidic rates of between 4.5 and 5.0, according to the study.

It is not just the Northeastern United States which is being pelted with acid rain. Our neighbors in Canada are also suffering the effects of this deadly precipitation. Canadian officials believe that between 2,000 and 4,000 lakes in Ontario are dead—that their fish populations have been wiped out because of acid rain. Those figures are in addition to the estimates that acid rain has wreaked similar destruction on at least 212 lakes in the Adirondack region on New York alone, with countless other comparable stories being told in other parts of the Northeastern United States.

I ask: What right do those who produce these poisonous emissions have to degrade these precious natural resources?

I am pleased to be the cosponsor of legislation attempting to halt this problem, introduced by our colleague from Maine, Senator Mitchell. This bill is a crucial first step toward combating the acid rain problem. It establishes a 31-State acid precipitation impact region consisting of all States east of the Mississippi River plus Minnesota, Iowa, Missouri, Arkansas, and Louisiana.

Sulfur dioxide and nitrogen oxide emissions in the region will not be permitted to increase over the total emissions inventory as of January 1, 1981, according to the bill. The legislation also calls for a reduction of 10 million tons in annual sulfur dioxide emissions, which now equal 25 million tons a year, and requires the Administrator of the Environmental Protection Agency to conduct a study on the effects of acid rain in the Southwest, the Great Plains, and the Northwest.

It is not the purpose of this legislation to create additional redtape and needless burdens for industry. Rather, it is important to recognize that this bill is a starting point from which we can begin to solve the problem of acid rain.

Senator STAFFORD. Senator Mitchell, it is appropriate for you to make a statement.

OPENING STATEMENT OF HON. GEORGE J. MITCHELL, U.S. SENATOR FROM THE STATE OF MAINE

Senator MITCHELL. Thank you, Mr. Chairman.

I want to thank you for scheduling this hearing, which I think will be an important addition to the committee deliberations on this very serious problem.

As you know, I have grave concerns about the damage that has occurred in the Northeastern United States and in Canada from acid deposition.

I am concerned about the resources that have been lost. But my more immediate concern is for the resources that have not yet been lost, but which are threatened by acid deposition.

Members of the committee are well aware of the loss of lakes and fish life that has occurred, so I will not get into those statistics now. My concern prompted me to introduce legislation that will provide some margin of safety for the vast resources now at risk.

While our understanding of the acid rain phenomenon is perfected, the effects of acid rain have been clearly manifested in the Northeast. But this may be only the first manifestation of an initial problem not limited to one geographic area.

Therefore, the loss of resources may be a warning, in a sense. We may be fortunate enough to have received that warning while we are able to devise a solution to prevent even greater damage.

I emphasize that we are not dealing with just a regional problem. The resources that have been lost and those that are now at risk belong to all Americans. We will all pay a price if we ignore the very real problem of acid rain.

We are here today to discuss this as a national problem. I have made my judgment clear. I believe we know enough to act now. Others disagree with that view, and I respect their disagreement. It is my hope that we can discuss those differences in a constructive way. The extent of resource damage, the economic value of documented and suspected damage, and the cost of control are all issues to be considered in devising an acid rain reduction strategy.

I do not suggest that my bill is a total or a perfect answer to the problem. I welcome constructive criticism that proposes improvement in my approach, and I, and I know other members of the committee, will consider them all with an open mind.

Mr. Chairman, I would like to include in the record a letter from the Governor of Maine who unfortunately could not be here today. I would also like to commend the Eastern States Attorneys General for the excellent submission to this committee and ask their report be made a part of the record.

Senator **Stafford**. Both of those requests will be granted and incorporated. (See pp. 119 and 127.)

Senator Baucus?

OPENING STATEMENT OF HON. MAX BAUCUS, U.S. SENATOR FROM THE STATE ON MONTANA

Senator **Baucus**. Thank you, Mr. Chairman.

I have a statement which I would like to have included in the record.

Before we continue the hearing, I would like to first commend you, Mr. Chairman, and Senator Mitchell, and Senators Randolph and Chafee, for their work in this area.

I fully understand the reluctance of some people to proceed with this kind of an approach, suggesting there is not a sufficient data base yet to adequately, comprehensively address the problem of acid rain. I might say, though, in my judgment, we do not have the time to wait. We must do the best we can with the information we now have.

I think Senator Chafee's analogy is a very apt one and a good one. Any neighbor who has garbage should pay the reasonable cost of disposing of that, rather than throwing it on someone else's property.

We here have an obligation to begin with the data we do have and find the most constructive way we can to prevent further dispersion of acid rain across the country because, in my judgment, we just cannot wait.

[Senator Baucus' opening statement follows:]

Mr. Chairman, The old saying "what goes up, must come down" is nowhere more apt than when talking about acid rain. In this case, however, the sulfur and nitrogen oxides which go up into the atmosphere travel hundreds and even thousands of miles before coming down in the form of acid precipitation.

The problem is significant and it is growing. Data from our Northeastern States and from eastern Canada demonstrating the adverse effects of acid rain on aquatic systems continues to mount. Thus, I am pleased that the committee will today have an opportunity to hear testimony relating to three proposals for the control of acid rain.

While there appears to be general agreement that acid rain exists, the agreement ends there. Unfortunately, acid rain is like a hit-and-run accident. The damage is done but the responsible party is tough to track down.

Nonetheless, I believe the outlines of a solution are increasingly clear. The findings of the National Commission on Air Quality point the direction, stating:

> A Commission study using state-of-the-art regional modeling techniques suggest that reductions in emissions of sulfur dioxide from sources in the Midwest reduce sulfur concentrations in the Northeast. For example, reductions averaging about 15 percent and 35 percent. * * * were projected to reudce annual sulfate concentrations in the Northeast by approximately 5 percent and 15 percent respectively."

While acid rain is principally thought of as a threat to the Northeast and to Canada, a symposium which I sponsored on this subject in Montana last year underscored the potential damage facing the West as well. Therefore, I believe that now is the time for us to devise an effective, responsible solution.

We cannot afford to wait for the last scintilla of evidence while watching the wholesale destruction of our lakes, streams, crop lands, and forests.

Thank you.

Senator Stafford. Thank you very much, Senator Baucus.

We will insert at this point in the record the statements of Senators Moynihan and Weicker.

[The statements follow:]

STATEMENT OF DANIEL PATRICK MOYNIHAN (D-NY)

I am most pleased to be here today as the Senate Environment and Public Works Committee conducts hearings on my bill, S. 1709 and Senator Mitchell's bill, S. 1706, both of which amend the Clean Air Act to provide for acid precipitation control programs and Senator Dodd's bill, S. 1718, which is designed to strengthen the existing interstate pollution provision in the Clean Air Act. My interest in the acid rain issue dates back some years.

In 1978 I co-sponsored a resolution (S. Con. Res. 465) calling for the Secretary of State to negotiate an air quality agreement with Canada. Acid rain was of course high on the list of transboundary air pollution problems articulated by the Canadians. Responding to this Congressional request, the U.S; joined with Canada to issue a statement on July 26, 1979 announcing the intention of both governments to develop a cooperative agreement on air quality. On August 8, 1980 a formal Memorandum of Intent was signed by the two countries and negotiations pursuant to this memorandum began in June of this year.

In 1979, based upon my concern that federal research on the acid rain problem and possible control strategies for it was under-funded and lacked coordination, I introduced the Acid Precipitation Control Act (S. 1754) which became law as Title VII of the Energy Security Act of 1980 (PL 96-294). As a result we now have an Interagency Task Force on Acid Precipitation that is embarking on a coordinated national assessment program.

While we do not know all there is to know about the acid rain phenomenon I feel the available evidence is clear that if we do not begin to act now we run the risk of causing irreversible damage to our environment.

This nation can wait no longer to control a problem which threatens to rob our lakes and waters of their life and which poses a possible hazard to human health. We should also be aware that the acid rain problem is one that continues to deeply trouble our neighbor to the north, Canada. The Canadians are taking action to limit the causes of acid rain from sources in their country. We can and must do the same.

I believe my bill, S. 1709, establishes a "reasonable and cost effective" program for controlling acid precipitation.

Under S. 1709, the 31 states bordering on or east of the Mississippi River would be declared an Acid Rain Mitigation (ARM) region. Within that region, states would be required to mandate substantial reductions in sulfur dioxide emissions -- the principal cause of acid rain -- between now and December 31, 1991.

Specifically, under terms of the legislation, emissions of sulfur dioxide within the region would have to be reduced by approximately 6.7 million tons per year in addition to the 1.5 to 2 million ton reduction already required by the Clean Air Act.

An estimated 22 million tons of sulfur dioxide emissions are poured into the atmosphere each year within the ARM region. Over 70 percent of these emissions come from fossil-fuel burning powerplants operated by utilities.

The amount of emission reduction in each state within the ARM region would be equal to an 85 percent decrease in actual sulfur dioxide emissions from the largest powerplants in the state. "Largest powerplants" in the bill are defined as those which emit over 50,000 tons of sulfur dioxide per year at rates greater than 3 pounds of sulfur dioxide per million British thermal units (Btu).

States would be given the right to amend their own air pollution control implementation plans, now required by the Clean Air Act, to meet the goals set forth in my bill. Moreover, states would be allowed to trade emission offsets with other states in the ARM region so that a regional strategy for controlling acid rain could emerge.

If states fail to meet the goals set forth in S. 1709, then the Administrator of the U.S. Environmental Protection Agency would be instructed to develop and enforce an appropriate plan for meeting the targets.

As I said on the Senate floor on October 6th when I introduced S. 1709, it is not unusual to find major issues such as acid rain generating multiple legislative proposals. A case in point is the Superfund legislation considered by this Committee and passed into law during the last Congress. In that instance we started, I believe, with five Senate bills. Working diligently and patiently, we forged a single piece of legislation that won the approval of the full Senate. I ask that we approach the crafting of a program to control acid rain with the same diligence, patience and I should add, good judgment. It is my sincere hope that my colleagues on this Committee will join together under the very able leadership of Senator Stafford to secure the inclusion of such a program in the upcoming Clean Air Act re-authorization legislation.

The witnesses that we have here today should provide us with additional insight as we review the pending legislative proposals. We have witnesses representing a variety of interests and I am sure a variety of viewpoints. I welcome their comments.

I would like to point out that in addition to the witnesses appearing before us today the National Research Council, a research group composed of engineers and scientists formed by the National Academy of Sciences in 1916, has provided this Committee with written testimony summarizing the findings contained in its recent report on the consequences of fossil fuel combustion on atmospheric pollution. In that report the Council concluded that continued emissions of sulfur and nitrogen oxides at current or accelerated levels will be "extremely risky from a long-term economic standpoint as well as from the standpoint of biosphere protection."

Finally I want to welcome Robert Flacke, Commissioner of the New York State Department of Environmental Conservation,who will be testifying today. New Yorkers have a keen interest in this issue. Large areas in the Adirondack region in New York have been found to be sensitive to acid precipitation. Fish and aquatic plant life are disappearing in numerous lakes in the Adirondacks. Both Governor Carey and Commissioner Flacke should be commended for calling attention to this problem and making meaningful contributions to the discussions about control strategies.

STATEMENT OF SENATOR LOWELL WEICKER, JR.
BEFORE SENATE COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS
DURING HEARINGS ON S.1706, S.1709 and S.1718
ACID RAIN LEGISLATION
ON OCTOBER 29, 1981

Mr. Chairman, acid precipitation, be it wet or dry in nature, is one of the major environmental problems facing us today and it looms as an ever worsening problem for the 1980's. With the conversion of many power plants from petroleum and natural gas to coal, emissions loadings of pollutants such as sulfur and nitrogen oxides (SO_2,NO_x) will increase and add to acid precipitation. The prospect of across-the-board relaxation of auto emmissions standards as proposed by H.R.4400, the Mobile Source Clean Air Act Amendments of 1981, could further compound the problem of not only acid precipitation but general pollution loading of carbon monoxide (CO) and hydrocarbons as well. This is not only a regional problem but also a global one. In fact the problem has placed a strain on our relations with our neighbor to the north, Canada. Many lakes in Canada and the United States are now devoid of most higher forms of animal life due to acidic precipitation and more are in imminent danger. The dollar value of the damage caused by this plight is already quite high. Unless we take action now to reduce our emmision rates of SO_2 and NO_x the problem will only become worse.

Acid rain causes numerous problems. Acid rains leach valuable minerals as well as mobilize toxic metals in the soil such as aluminum, copper and lead. Through bioaccumulation toxic metals can become highly concentrated in our food chain and can pose a serious health hazard. In addition, acidic waters transported through metal pipes can corrode those pipes, causing toxic metals to go into solution and come out of the tap into our drinking water. Acidic influx into bodies of water can increase the levels of methyl mercury in fish which in turn can be quite harmful to man. Also, acid mists may even be implicated in lung problems such as emphysema as well as certain heart ailments. In addition acid rain corrodes many man made structures, such as monuments, buildings and car finishes.

The scientific evidence amassed shows a direct correlation between SO_2 and NOx emissions, coming mainly from power plants, and automobiles respectively, and acid precipitation. The National Academy of Sciences, in October 1981, issued a report entitled: "Atmosphere-Biosphere Interactions: Toward a Better Understanding of the Ecological Consequences of Fossil Fuel Combusion", in which it states that the "increased emissions of sulfur and nitrogen compounds from anthropogenic sources is the only plausible explanation for acid deposition" and that evidence of a close relationship is "overwhelming". Considering what we already know to be true, the time has come to take legislative aciton to alleviate the problem.

Industry representatives, as well as the EPA, feel that more studies are needed to prove a direct correlation between acid rain and SO_2 and NO_x emissions before any legislative action is taken. Industry is also rightfully concerned about the cost of emissions reductions as well as possible work force dislocation. In my opinion the correlative evidence is more than sufficient to warrant legislative action. The economic costs may be substantial but the costs of failing to act now will be immeasurably greater for ourselves and future generations.

Another major factor in dealing with acid rain is the interboundary transport of acid precipitation between the U.S. and Canada. Acid rain is going over the border in both directions, but most of it is coming from America. We owe it to our neighbors, as stated in the Memorandum of Intent between the Government of Canada and the Government of the United States of America Concerning Transboundary

Air Pollution, to "recognize this" as "an important and urgent bilateral problem". Legislative action would effectively demonstrate "a common determination to combat transboundary air pollution."

The legislation before us is a good beginning because it reduces emissions substantially and therefore addresses the problem at its source. In addition, S.1718 is a needed mechanism whereby the states can have an easier time proving and redressing interstate interference with pollution level compliance. I might add that since Connecticut has one of the most stringent sulfur dioxide standards of any state, the problems associated with interstate transportation of pollution are of even greater concern to us than they might be to a highly polluting state. The Connecticut State Department of Environmental Protection estimates that emissions from the North Port and Port Jefferson power plants , located in Long Island, N.Y., are greater than emissions of all Connecticut fuel burning sources even after Connecticut sulfur-in-fuel requirements were raised to 1%. Canada, although not taking an official position on any particular bill, is wholeheartedly behind the intent of these proposals.

The environmental implications of continued increased acid rain are not good. Possible health hazards associated with acid precipitation cause reason for even greater alarm. The economic payoffs for addressing this dilemna, both tangible and intangible, are great. A Harris Poll taken in September 1981 shows that a convincing majority, 80 percent of the public, is opposed to any relaxation of current air pollution laws. As Louis Harris states, "this message on the deep desire on the part of the American people to battle pollution is one of the most overwhelming and clearest we have ever recorded in our 25 years of surveying public opinion." This keen interest on the part of the American public in keeping the air clean should give us ample reason not only to keep the status quo but continue to decrease air pollution in as many ways as technologically, economically, and rationally possible.

The United States and Canada have agreed to jointly combat this Problem. This agreement will be more forcibly carried out if legislation setting forth this country's method of dealing with acid precipitation is passed. We must act now and initiate these reforms.

Senator **Stafford**. Now the committee is very pleased that one of our colleagues, a distinguished Member of the Senate, Dave Durenberger, is here to be the leadoff witness.

Having known Senator Durenberger long and well, I hail his presence as the leadoff witness, as an architect of constructive thinking and legislation in this Senate of ours for many years.

Senator Durenberger, we would be pleased to hear your testimony.

STATEMENT OF HON. DAVE DURENBERGER, U.S. SENATOR FROM THE STATE OF MINNESOTA

Senator **Durenberger**. Mr. Chairman and distinguished members of the Environment and Public Works Committee, I appreciate the opportunity to have gotten here earlier and sensed the commitment on the part of every one of the members of this committee to the task that lies before you.

Atmospheric pollution has been a concern of mine since taking office. In the fall of 1979, I established an advisory committee on the issue with Federal and State agency staff, representatives from business and industry, environmental groups and distinguished members of the scientific community from my State of Minnesota, which probably has experienced and will experience the effect of acid deposition greater than many States in this country.

Although acid deposition has long been recognized as a serious problem primarily in the Northeastern United States and Canada, as Senator Mitchell pointed out, continuing research has led to the recognition that my State of Minnesota and other Upper Midwestern States are faced with great environmental, economic, and health loss as a result of acid deposition.

Our distinguished colleague, Senator Randolph, spoke about the problems of the air that people and animals breathe. I will talk to you briefly about the problems of fish life and those appropriate implications for States like Minnesota, as well as the people and animals.

In the northeastern region of Minnesota, the location of the magnificent Voyageurs National Park and Superior National Forest, which includes the 1-million acre Boundary Water Canoe

Area wilderness, unique in this Nation, research has found an average pH of rain that is 10 to 25 times more acidic than the normal pH value of 5.6. Recently, the average pH of rain in this area was measured to be 4.2. The lowest recorded value in northeastern Minnesota was 3.6 at Hovland, Minn., a town near the Canadian border. This is 100 times more acidic than "normal rain."

Research conducted by Dr. Gary E. Glass and other EPA scientists indicates that at least 35 percent of the lakes in northeastern Minnesota have reached critical acidity levels—please don't say we have 10,000 lakes, we can do away with 3,500—even without the addition of new pollutants.

The Minnesota Pollution Control Agency staff calculates the Boundary Water Canoe Area Wilderness is receiving loadings shown to cause acidification in Scandinavia.

The diverse and valuable fishery of this area of Minnesota include species which have been greatly reduced or eliminated by acid rain and snow in other parts of the United States and Canada. While damage there has been less than in the Northeast, studies have shown increased levels of mercury in trout, walleye pike and northern pike which may well have resulted from acid deposition. Fish kills not only result from the direct effects of acidic lake water, but also from the toxic metals, such as aluminum, that are released as acid rain is transported through surrounding soils.

The threat to the forests of Minnesota is also of great concern. Acid deposition in northeastern Minnesota's Superior National Forest may affect the growing rates of sensitive pine species and cause detrimental effects on other vegetation.

Acid deposition therefore defies the premises on which our current air pollution policy rests, for it is confined to no single State, and the effects occur great distances from its sources.

The acid rain phenomenon is real, man-made, and damaging. Reduction of emissions impacting affected areas is a necessity. This is not to say that research should not be supported. It must continue with adequate funding. However, we must start to reduce emissions as is directed in S. 1706, of which I am pleased to be a cosponsor.

S. 1706 is of particular importance because it take steps to protect resources whose buffering capacity has been reduced but not exhausted. Acid deposition is the most serious new air pollution problem to emerge since Congress last revised the Clean Air Act and should be dealt with during this reauthorization of the act.

S. 1706 proposes a 10 million ton reduction of sulfur dioxide emissions in the acid deposition impact region over a 10-year period. This is approximately 40 percent of total sulfur emissions in the region now from all stationary sources.

Minnesota has demonstrated its concern over air quality by establishing stricter air quality standards than those required by Federal law. This has prevented our neighbors' garbage from coming into our yard.

Only seven States have ambient standards as strict as those set by the Minnesota Pollution Control Agency.

Minnesota's ambient air quality standards are 50 percent more restrictive for SO_2 and ozone than the Federal standards.

The average emission rate in Minnesota for SO_2 is 3 pounds per million Btu's, three times lower than some states upwind of Minnesota. There are single powerplants in Kentucky and Ohio that individually emit more SO_2 than the entire State of Minnesota which contributes only 1 percent of the Nation's SO_2 emission.

Minnesota citizens are paying more for air quality control than many States, yet the State cannot protect itself from the effect of transboundary transport acid deposition. Minnesota Pollution Control Agency staff estimates that only 30 percent of acid rain falling in Minnesota is due to emissions in the State. The balance originates elsewhere.

Meteorological studies done under the auspices of the EPA by Dr. Walt Lyons and others have clearly documented the existence of gigantic swirling weather systems that move huge masses of air pollutants in all directions from the major source regions of the Ohio River Valley. It is a mistake to rely on simplified textbook notions of the "prevailing westerlies," moving air only from west to east.

S. 1718 would improve the process established in the Clean Air Act to provide States with relief from long-range transport that adversely affects the petitioning States' air quality. Section 110 and section 126, the provisions of the Clean Air Act that deal with this issue, have proved to be unworkable.

S. 1718 is a more comprehensive approach to dealing with interstate transport than is presently provided under the provisions of the Clean Air Act, and should go far to address the concerns of those engaged in the day-to-day administration of the Clean Air Act.

The issues of interstate responsibility is of critical importance. Although the details of S. 1706 and S. 1718 may require further examination and debate, as you are here today engaged in, the need to proceed is clear.

I congratulate you, Mr. Chairman, on your willingness to do so.

Senator STAFFORD. Thank you very much, Senator Durenberger, and we appreciate it.

If my colleagues have questions at this point, we will take a minute for them. I would have just one.

In noting in your statement the fact that three upwind States are apparently dumping their garbage on Minnesota, has any lawsuit been brought in connection with that practice?

Senator DURENBERGER. Not that I am aware of, Mr. Chairman. This is a problem we try not to learn to live with. I would just add to my statement we have held hearings in the Intergovernmental Relations Subcommittee—some of the applications of the State's role in carrying out the regulations, such as the Clean Air Act, and we find this problem exists all over the country, a multistate approach. I think to a degree, at least, the Governors of the States involved are struggling with some form of solution that is multistate and not necessarily federally imposed, although I do think we have a role to play in it.

Senator STAFFORD. Thank you very much.

I would remind my colleagues we have a long list of witnesses, but we certainly don't want to leave out the opportunity for questions.

Senator Randolph, do you have any questions?

Senator RANDOLPH. I commend our colleague on the constructive statement he has given.

Thank you.

Senator STAFFORD. Senator Chafee?

Senator CHAFEE. No.

Senator STAFFORD. Senator Mitchell?

Senator MITCHELL. No. I thank Senator Drenberger for a fine statement. I have no questions.

Senator STAFFORD. Senator Baucus?

Senator BAUCUS. No questions.

Senator STAFFORD. Senator Moynihan?

Senator MOYNIHAN. I just thank our colleague for making an important point about the weather systems. These are swirling systems, not just a simple corridor.

Senator STAFFORD. Thank you, Senator.

I think your statement has been excellent and very helpful to this committee. We appreciate your help.

We understand you may have other appointments and may wish to leave.

The Chair observes Senator Dodd of Connecticut has now joined us and we would be more than pleased to hear him.

Just before you begin, the Chair would place in the record a statement by Senator Claiborne Pell on this subject, if there is no objection.

Hearing none, it is so ordered.

[Senator Pell's statement follows:]

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United States Senate
COMMITTEE ON
RULES AND ADMINISTRATION
WASHINGTON, D.C. 20510

October 29, 1981

The Honorable Robert T. Stafford
Chairman
Committee on Environment and
Public Works
United States Senate
Washington, D.C. 20510

Dear Mr. Chairman:

I am very interested in the problem of acid rain and the control measures that your Committee on Environment and Public Works will be considering at today's hearing.

Prior commitments to other hearings made it impossible for me to request an opportunity to testify, but I hope you will enter the enclosed statement in the record of the hearing.

As I note in the statement, I strongly support the Acid Deposition Control Act (S.1706) and commend you and your Committee for addressing this serious problem directly.

Warm regards.

Ever sincerely,

Claiborne Pell

Enclosure

STATEMENT BY SENATOR CLAIBORNE PELL

ACID RAIN--A GROWING THREAT

Mr. Chairman, thank you for this opportunity to submit testimony to the Senate Environment and Public Works Committee's hearing on the growing problem of acid rain and on specific legislative remedies.

I have asked that my name be added as a cosponsor of the Acid Deposition Control Act (S. 1706), introduced earlier this month by Senator Mitchell. I strongly support this legislation and commend you and your committee for these important hearings.

We urgently need to address the problem of acid rain by taking action and we must not be satisfied with merely continuing to study the problem. The action detailed in S. 1706 is a sound step in the right direction and I am truly encouraged to see growing bipartisan support for it.

This legislation, as you know, would require a ten million ton--40 percent--reduction in sulfur dioxide releases over the next decade in the 31 states along the Mississippi River and east of the river. It also would require that sulfur and nitrogen oxide emissions be held down to no more than their January 1, 1981 levels.

In my own state of Rhode Island we suffer from acid rain, largely attributed to air pollutants emitted in states to the south and west of Rhode Island. Although our own emissions are slight, transported pollutants from other states are believed to threaten our waters, marine life and even our buildings.

Rhode Island is one of 15 states that have been identified as "extremely vulnerable" to the harmful effects of acid rain. This identification was made in a National Wildlife Federation study of 26 states east of the Mississippi River.

Our rainfall in Rhode Island averages 4.4 on the pH scale. The pH scale, on which zero is most acid and 14 is most alkaline, sets the neutral level of distilled water at 7 and normal rainfall as slightly acidic at 5.6. Each numerical decrease means a 10-fold increase in acidity.

Although 4.4 was identified by the study as our average rainfall, I have been advised by officials in the Department of Environmental Management's Division of Air and Hazardous Materials that Rhode Island is seeing rainfall even higher in acidity--in the range of 3 to 4 on the pH scale.

Michael North, the senior air quality engineer in the division, noted that vinegar has a pH of 3 and that Rhode Island's rainfall "is very acidic at times" and is close to vinegar or lemon juice in acidity.

Most waterways in Rhode Island have very low buffering capacities and, although no obvious symptoms have been observed, the Department of Environmental Management's Division of Fish and Wildlife records indicate a threatening increase in acidity over the years in our waterways.

The Scituate Reservoir, for example, which supplies drinking water to our capitol city of Providence and several neighboring communities, has an average pH of 6. This is a high acid content for surface water, especially for productive water. Levels of 6 pH and lower have been found to threaten fish reproduction.

Other waterways in Rhode Island have been found to be far more acid than the Scituate Reservoir. Some lakes, such as one in Exeter, Rhode Island, have been measured at 4.6 pH --extremely low on the scale and threateningly high in acidity. Studies have found that most fish species die at acidities between 4.5 and 5.0 pH.

There is no question that acid rain exists and little doubt that it is caused when sulfur and nitrogen oxide emissions from coal-burning power plants, motor vehicles and other sources combine with rain and snow.

There also is a growing body of evidence that acid rain also threatens even the buildings we erect-- sometimes as the seat of our governments. I understand that the Old State House, a limestone building in Providence, and our new State House, a marble building, are vulnerable to acid rain. Both limestone and marble deteriorate as they are gradually eaten away by acid rain.

An expert panel of the National Research Council, in a recent statement in favor of tightening restrictions on emissions, noted that "continued emissions of sulfur and nitrogen oxides at current or accelerated rates, in the face of clear evidence of serious hazard to human health and to the biosphere, will be extremely risky."

I hope and trust that we will not take that risk. We must not wait until our buildings crumble, our water turns to vinegar and our fish disappear. It is incumbent upon us to act now to control the emissions that cause acid rain and I am encouraged by the growing support for those controls.

I believe that the Acid Deposition Control Act would strengthen the Clean Air Act and I continue to believe that strong environmental legislation is an investment in our future and a key to preserving the public health.

Thank you.

Senator STAFFORD. Senator Dodd, we would be very happy to hear you.

STATEMENT OF HON. CHRISTOPHER J. DODD, U.S. SENATOR FROM THE STATE OF CONNECTICUT

Senator DODD. Thank you, Mr. Chairman.

I appreciate the opportunity to appear before you this morning, and I want to commend you, Mr. Chairman, and the entire committee, on the outstanding effort you have put into this revision of the Clean Air Act.

As you know, last week, before this hearing was scheduled, I sent to you, Mr. Chairman, and to the distinguished ranking minority member of the committee, an extensive statement on my views on the Clean Air Act. I will not repeat the entire text of that statement, but ask that it, with a letter of transmittal, be included in today's hearing record. (See p. 87.)

As the author of S. 1718, a bill designed to strengthen the interstate pollution prohibitions in the Clean Air Act, and as an original cosponsor of S. 1706, Senator Mitchell's acid deposition bill, my general sentiments on these proposals are clear. The need for legislation to address these two issues has been widely recognized for some time. Action on both issues was recommended by the National Commission on Air Quality which was cochaired by the chairman of this committee and the Senator from Colorado, who also served on it.

I introduced S. 1718, with Senator Durenberger, on October 7, as a means of calling attention to what I consider to be one of the most crucial issues this committee and this Congress must resolve in revising the Clean Air Act. I consider the fact that this hearing is being held to be more important than the specifics of the language of my proposal or of other proposals that have not yet been formally presented. I am confident that this committee will address the interstate pollution language of the Clean Air Act when it marks up the revised bill and hope that today's hearing will provide a firm basis for making the needed changes.

I would like to take this time to emphasize what I consider to be the three essential elements of any meaningful revision of the interstate pollution sections of the Clean Air Act.

First, section 110(a)(2)(e) of the act must require State implementation plans (SIPs) to contain provisions prohibiting emissions from groups of sources, including mobile sources, that would harm another State. The act's current provisions appear to require only that emissions from stationary sources be controlled to prevent interstate pollution. Some have asserted that this prohibition applies only to emissions from single stationary sources and does not even include concentrations of industrial facilities with total emissions at levels that hinder clean air efforts in neighboring States. It should be made clear that neither the number or types of sources generating pollution transported to another State is the issue. The issue is whether or not pollution generated in one State is harming the air quality in another State.

The second essential element is that the threshold for determining an interstate pollution violation must be reasonable.

The current threshold, that a source be shown to "prevent attainment or maintenance of national ambient air quality standards," is not a reasonable or a practical standard. Attempting to determine precisely which emissions prevent attainment of air quality standards is like trying to determine which straw broke the camel's back. We do not have the technological capability to determine precisely which increment of air pollution is the most harmful. The act should recognize this and establish reasonable criteria for evaluating both local and interstate contributions to air pollution.

Third and finally, regarding interstate pollution revisions, such provisions must be enforceable and they must be enforced by the Environmental Protection Agency. Current law requires that the Administrator reach a finding within 60 days of an interstate pollution petition. Of the seven petitions that have been filed under section 126 of the act, only one has been acted on by the EPA. That petition, filed on behalf of Jefferson County, Ky., against emissions from a power plant in Indiana, was filed in May 1979. In July 1981, 26 months later, the EPA proposed a denial of the petition.

In the cases of two section 126 petitions filed by my State of Connecticut in April and August 1980, the EPA has yet to make a finding. In spite of this, the EPA in August of this year approved the New York State Implementation Plan revision against which Connecticut filed one of its petitions.

Yesterday I received from the Environmental Protection Agency a summary of the status of all section 126 petitions filed to date. I believe, Mr. Chairman, this summary makes the need for a strong enforcement mechanism irrefutable and ask that it be included in the hearing record.

Mr. Chairman, I strongly would urge the committee to adopt these principles when it takes up the Clean Air Act revisions. The specific proposal Senator Durenberger and I have put forward as S. 1718, in my opinion, accomplishes these objectives and I would like to thank the committee in advance for its serious consideration of this proposal. If the committee, in its wisdom, feels there is a better way of achieving those principles, you are going to have our support.

As I mentioned, I am also a cosponsor of Senator Mitchell's bill, the Acid Deposition Control Act. My full statement to the chairman and my remarks on S. 1706 in the Congressional Record on October 7, 1981, outline my specific views on S. 1706 and the acid rain problem in general.

At this time I would like to emphasize my conviction that the evidence we have now concerning the causes and potential harm of acid deposition is more than sufficient to warrant the enactment of the Acid Deposition Control Act as an amendment to the Clean Air Act. I am convinced that there will be lengthy debate over the details of any "acid rain" provisions this committee considers. There will be compromises as there should be on any legislation of this importance and magnitude. But those compromises should not abandon the principal objective of S. 1706 and similar proposals, and that is: To achieve a significant reduction of sulfur dioxide and nitrogen oxide emissions in the United States within the next 10 years. Even if we cannot today predict how much reduction in acid deposition will be accomplished by a 10-million-ton reduction in SO_2 emissions, the overwhelming weight of evidence is that without this reduction acidity will continue at unacceptable levels.

On behalf of Connecticut I would like to make one point to the committee. I am convinced that my State is willing to bear its fair share of the burden under any program to bring the acid deposition problem under control. I think the committee should be aware of the fact that Connecticut has had the most stringent sulfur dioxide control standards of any State in the United States.

Until this week, major oil-burning facilities in Connecticut have not been allowed to burn fuel containing more than one-half of 1 percent sulfur. A State implementation plan revision approved by the EPA this week will allow a number of Connecticut utilities and industrial facilities to burn 1-percent sulfur oil. This 1-percent standard is still well below the sulfur content allowed in most major facilities in other States.

While this change will probably result in some increase in total sulfur emissions from all sources in Connecticut, total sulfur dioxide emissions from all Connecticut sources will continue to be among the lowest in the Nation. I urge the committee, in considering SO_2 reduction requirements for the control of acid rain, to take into account the reductions previously achieved by Connecticut and other States that have already taken strong steps to control these emissions.

One further matter which I would like to address briefly is the assertion raised by some opponents of efforts to control acid rain that the acid rain issue was manufactured by the Canadians to distract attention from other domestic problems or as a means of fueling anti-American sentiment in Canada. Every member of this committee I believe knows that the acid rain problem was first raised in Canada by Mr. John Fraser when he was the Minister of Environment under the conservative government of Joe Clark. In addition, Mr. Fraser and representatives of the other two major political parties in Canada have made it clear that the Government's policy on acid rain will not change no matter which party is in power.

Finally, on this point, my support for an acid rain control program, and I am sure the support of Senator Mitchell, Senator Moynihan and all other sponsors and cosponsors of acid rain legislation derives principally from the fact that acid deposition is a problem in Connecticut, in Maine, in New York, in Vermont and in numerous other States of this Nation.

The fact that it is also a problem, and a serious one, for Canada and its provinces only adds impetus to the need to control the problem. We are not doing Canada a favor nor yielding to blackmail by proposing these measures. We are attempting to protect our own people and our own States' resources.

In closing, Mr. Chairman, I would like to submit for the record letters of endorsement of S. 1718 from my own Governor, from the attorney general of my State and from the Connecticut Chapter of the Sierra Club. (See pp. 109 and 112.) In addition you have either received or will receive from the attorneys general of Connecticut, Vermont, Maine, New York, New Hampshire, Rhode Island, New Jersey and Massachusetts a report detailing their recommendations for amendments to the Clean Air Act. Those recommendations focus largely on the problem of interstate air pollution.

Mr. Chairman, I believe the committee and the entire Congress could profit substantially by a close study of these recommendations

I understand this morning Senator Mitchell has already requested that information be included in the record.

Mr. Chairman, I thank you again for allowing me to appear before you this morning. Let me emphasize again I am not wedded to any specifics in this. I think the essential principles are important. I hope that in the wisdom of this committee, you will come forward with legislation that will confront and meet those essential principles. Even though we in the Northeast and Midwest are most affected by interstate transported pollutants it is a national issue and it affects practically every State in the country.

I appreciate, again, the chance to appear before you.

Senator STAFFORD. Thank you again, Senator, for your very helpful testimony, and your request for matters to be in the record, without objection, is granted.

Senator STAFFORD. I shall confine myself to simply expressing our thanks.

Do any members of the committee have questions?

Senator Moynihan?

Senator MOYNIHAN. Mr. Chairman, I would just like to particularly thank Senator Dodd for raising this question of the sources of the Canadian concern. Perhaps it is now appropriate if I could just take a moment of the committee's time to agree most emphatically with you. I have been following this particular subject with some care and introduced the measure which became the Acid Precipitation Act of 1980, and in that capacity have held hearings and gone around the Northeast and to Canada. Nothing could be more emphatic than the all-the-party concern of this matter in Canada, and nothing could be more impressive than the intensity of the concern.

I am sorry to say that the administration seems to be looking around for some reasons. There is that story of the occasion at the Congress of Vienna when Metternich was told the Russian Ambassador just dropped dead, and he rubbed his eyes and said, "What can have been his motive?"

The motive is we are poisoning their lakes. Their lakes are very important.

I was in Buffalo, Mr. Chairman, last spring, to meet on this matter, and there was the equivalent in the Canadian Foreign Ministry of the Secretary of State. He was there in Buffalo wanting to talk about this matter. He arrived with the full group. There was not even a vice consul to meet him. Our Secretary of State was on his way to Rome on a meeting.

Mr. McRee was also on his way to Rome to the same meeting. But this matter was of concern.

I held a hearing in Albany last summer on what is Canada Day, on their "Fourth of July," and half the members from the Ontario Cabinet, who ordinarily would be making speeches on that day, were in Albany testifying, pleading with us, "Can we not see something very important in our relations is involved here?"

And it is nothing to do with anybody's politics up there. It has a great deal to do with our respect for our single most important other country in our national lives.

I thank you for raising that.

Senator DODD. Thank you.

Senator STAFFORD. Thank you very much.

Senator Chafee?

Senator CHAFEE. Mr. Chairman, I would like to briefly comment on the Canadian situation. I completely agree with the remarks Senator Dodd made. John Fraser was down here last week. We had a chance to meet him. Any suggestion that this is Canada trying to divert attention from any other situations you mentioned is just not so. This is a deep concern.

Frankly, I had never heard of acid rain until I attended the Parliamentary conference with the Canadian Members of the Parliament about 4 years ago in Calgary. There they raised that issue. It was across the board, regardless of their party, whether they were liberals or conservatives. They were deeply concerned.

As you know, Mr. Fraser is not even in the government. His party is not there. But he is concerned, and his successor in the incumbent liberal government is as deeply concerned.

So I am glad you raised that point, and I think it is a good one to make.

Senator STAFFORD. Is there any further comment?

Senator Randolph?

Senator RANDOLPH. Yes, Mr. Chairman, thank you very much.

Senator Dodd, what you are saying is indicative of a substantial body of thought in the Senate, Members from all parts of the country, as to new, more appropriate and, constructive and necessary action in this area. We in our office and certainly within the committee have had conferences with the Canadian officials who serve here, including the Ambassador of that country. And what has been said by Senators Moynihan and Chafee I am in full accord with and want to say we must not divert to other subject matter a question of this kind. I don't believe that will be inherent in what we do.

We have no rule against smoking in this committee, but I just want to commend all of you who, whether you smoke in private or not, that you are not contributing to pollution by your sitting quietly without smoking during this hearing.

Senator STAFFORD. Thank you very much, Senator.

Senator Hart?

Senator HART. Mr. Chairman, although I know this is not particularly responsive to Senator Dodd's excellent statement, I would like to call attention to a fact that I know Senator Baucus and I and some of the rest of us are aware of how volatile issues are.

When the National Commission on Air Quality began to look at the acid rain problem and began to focus attention on this a year or two ago, in the course of that investigation, another phenomenon emerged; that is, as important as acid rain is a regional issue in the Northeastern part of this country, and in our neighboring country of Canada, it is also becoming a Western issue, and we have begun to discover that serious acid rain problems are emerging in the Rocky Mountain West.

I want to indicate to my colleagues, as important as controlling the sulfur dioxide emissions is, which accounts for most of the acid rain in the East, in the West we have another phenomenon, and that is the nitrogen oxide problem. We will not be able to control acid rain in the Rocky Mountain West without some fairly strong controls on the nitrogen dioxide or nitrogen oxide emissions from automobiles.

So what I hope to do in the committee is not only support my colleagues in the Northeast with the serious problems that sulfur dioxide emissions are causing, but also solicit their support for those of us, including Senator Baucus and me, in the West who want to combat this problem at the earliest possible date. We will need the support of those in the East to continue reasonable strong controls on auto emissions where nitrogen oxides are concerned.

I just want to flag that and say I think we are going to have to focus, when we get to marking up the bill, on exemptions incorporated in the act earlier for smelters. We have been exempting smelters for economic reasons and we are not going to be able to get at the acid rain problem in the West without bringing those smelters under the control of the act.

So I thank the chairman and thank Senator Dodd.

Senator DODD. In your absence, Gary, I had mentioned the tremendous job that the Commission had done, in fact had made strong recommendations in this area. I think the information about the West being a victim of acid rain as well is extremely important.

Senator STAFFORD. Thank you very much, Senator Hart. I think you made a valid point.

I noticed figures that indicated the atmospheric loading in this country from sulfur dioxide was on the order of 26 million tons and the loading of nitrogen oxide was 23 million tons. So the two are close.

Senator Mitchell?

Senator MITCHELL. I just want to commend Senator Dodd for a very forceful and effective statement. Obviously he put a great deal of time and study into the problem. He is very conscious of and is providing great leadership in the area and I want to thank him for his statement.

Thank you, Senator Dodd, for helping us out.

Senator STAFFORD. The next witness will be Dr. Robert Friedman, Office of Technology Assessment.

Dr. Friedman, we welcome you here. We would ask, if you could, to summarize your statement in 10 minutes, and whatever data, graphs are attached to it, we will make a part of the hearing record, along with the full statement.

STATEMENT OF ROBERT M. FRIEDMAN, CONGRESSIONAL OFFICE OF TECHNOLOGY ASSESSMENT

Mr. FRIEDMAN. Thank you, Mr. Chairman.

I thought I was going to have an overhead projector available, but we had some problem finding an outlet.

I am Robert Friedman. I am with the Congressional Office of Technology Assessment and currently direct the OTA study on the "Impacts of Atmospheric Alterations."

The assessment was requested by this committee and the House Committee on Energy and Commerce. Our study concentrates on a broad range of issues associated with the potential impacts of controlling, or not controlling, long-range transport air pollutants. Our study is still underway and therefore the information that I will present this morning has not been reviewed by either our advisory panel or the Technology Assessment Board.

This morning, Mr. Chairman, I would like to discuss the implications of two bills framed to control acid deposition—S. 1706 and S. 1709. Both bills require sulfur dioxide emission reductions in an eastern region comprised of the 31 States bordering on or east of the Mississippi River, and the District of Columbia.

I would like to focus my remarks on:

First, estimates of the required emission reductions for each state as specified by S. 1706 and S. 1709.

Second, model-based estimates of the cost of emissions reductions specified by these two bills. I would like to state at the outset that these cost figures assume that reductions are accomplished solely by decreasing utility emissions of sulfur dioxide, even though both these bills allow emission reductions to be achieved in other ways.

For 1980, sulfur dioxide emissions in the 31 Eastern State region were estimated to be approximately 22.5 million tons. Utility sulfur dioxide emissions were estimated to be about 16 million tons, or about 70 percent of the total.

Because of the design of both the Mitchell and Moynihan bills, calculating State-level emissions reductions specified by each bill requires the use of a utility inventory that accounts for emissions on a plant-by-plant basis. The utility emissions inventory we have used, which we believe is the best available, includes estimated emissions from all major fossil-fuel electric generating plants in the United States.

The Mitchell bill requires that the amount of sulfur dioxide and nitrogen oxides emitted from the Eastern 31 States and District of Columbia not exceed the amount of each of these pollutants emitted from the region as of January 1, 1981. Moreover, the bill requires that within 10 years of enactment, sulfur dioxide emissions from the eastern region be reduced to 10 million tons less than the actual amounts of sulfur dioxide emitted during 1980. This is a sulfur dioxide emissions reduction from about 22.5 million to 12.5 million tons per year, or about 45 percent of 1980 emissions for the region.

However, it is important to note that under current laws and regulations embodied in State implementation plans, or SIP's, some States are required to decrease present sulfur dioxide emissions. In fact, approximately 1.5 of the 10 million ton reduction specified by S. 1706 is already required under existing SIP's.

The Moynihan bill is similar to the Mitchell bill in that it specifies the same Eastern State region and allows States the same flexibility in implementing reductions. However, it differs from the Mitchell bill in that it does not specify sulfur dioxide emissions reduction by tonnage; Rather, the emissions reduction target is a percentage of actual emissions from only the largest electric-generating plants.

We estimate this includes 50 to 75 plants in half the States in the 31-State region.

By our analysis, the sulfur dioxide emission reductions specified by the bill are about 6.7 million tons. As mentioned previously, a 1.5-million-ton reduction in sulfur dioxide emissions is already required by existing SIP's.

Given the wording of the Moynihan bill, the total emission reduction achieved under the bill is about 8 billion tons of sulfur dioxide when we add the amount due to SIP's.

I would now like to compare the two bills.

Though both bills calculate emission reductions by considering electric utilities only, they allow the States to obtain emission reductions from any source within the State, from other sources than the utility industry, by obtaining emission reductions from other States, and by substituting nitrogen oxide emission reductions for sulfur dioxide.

Another point in common is that both bills specify State-level emission reductions by a formula based on the rate of sulfur dioxide emissions. Therefore, States with electric-generating plants emitting at the highest rates will receive the largest share of emission reductions.

My third point is that calculating the reductions specified by either bill with the accuracy required for regulation is a difficult task, and thus may present implementation problems.

Some of the important differences between the Mitchell bill and Moynihan bill are:

First, including all other State and Federal laws regarding emissions reductions, the Mitchell bill results in about a 10-million-ton reduction, and the Moynihan bill, about an 8-million-ton reduction from 1980 emission levels. This is a 45 percent and 36 percent reduction, respectively, from 1980 emissions of sulfur dioxide.

We have State-by-State totals listed in my prepared statement.

The Mitchell bill allocates emissions reductions to almost all the States in the Eastern United States; the Moynihan bill, to about half the Eastern States.

I would like now to discuss the regional costs.

Rather than making single estimates of the costs of the Mitchell and Moynihan bills, we have developed a range of estimates corresponding to different assumptions as to how the emission reductions might be accomplished at the State level.

We estimate the reductions specified by the Mitchell bill will range from $3.3 to $4.1 billion per year. The costs associated with the Moynihan bill range from an estimated $2.2 to $2.6 billion per year. These costs are first year, annualized costs. They are estimates using a well-known utility model modified by one of our contractors.

It should be noted these estimates do not include the cost for emissions reductions required under current law. The lower estimates, $3.3 billion for the Mitchell bill and $2.2 billion for the Moynihan bill, assume that each State will choose the most cost-effective way of meeting the emission reductions.

This might occur by some intrastate trading mechanism or by a State's requiring emission reductions from those plants that can reduce emissions least expensively. However, no interstate trading occurs.

In the upper estimates, $4.1 billion in the Mitchell bill and $2.6 billion in the Moynihan bill, each State would achieve required reductions by imposing uniform emission ceilings on utilities.

For comparison, in my prepared statement I have also provided an analysis of a scenario under which emissions reductions would be accomplished by choosing the least-cost strategy of achieving reductions in the entire 31-State region through interstate trading. This strategy assumes a "perfect market" with total freedom to trade emissions across the entire region.

If this least cost regional approach were possible, the emission reduction targets of the Mitchell and Moynihan bills could be achieved at a cost of $3.1 billion and $1.7 billion for the Mitchell and Moynihan bills respectively.

To put these cost estimates in perspective, the Congressional Budget Office has estimated the total cost for utility air pollution control in the United States in 1980 to be about $6 billion.

The cost estimates generated by the computer model we are using must be considered approximate, because we could not fully incorporate the provisions for flexibility in achieving emission reduction specified in both the Mitchell and Moynihan bills. Let me list a few of the constraints of our analysis:

First of all, our analysis assumes that all reductions are accomplished immediately, without accounting for new plants being built or old plants being retired.

Second, we do not consider substituting industrial reductions for utility reductions.

And third, we do not consider substituting nitrogen oxide reductions for sulfur dioxide reductions.

I would like to comment on the provisions of both bills which allow for trading nitrogen oxide emissions for sulfur dioxide. At the current time, our knowledge of baseline nitrogen oxide emissions is quite poor, relative to sulfur dioxide. It is harder to estimate the amount of current emissions on a plant-by-plant basis. In addition, the current knowledge of the available options and costs of controls for nitrogen oxide emission reductions is much poorer than for sulfur dioxide reductions.

In our final report on transported air pollutants, scheduled for completion next spring, we hope to provide a more complete discussion of the cost of air pollution control. While my testimony today has focused on the costs of utility emissions reductions specified by the two bills, another major element of our study, which I have not discussed at all in this testimony, is an examination of the potential benefits of controlling transported air pollutants. This concludes my written statement, Mr. Chairman. I will be happy to answer any questions.

Senator STAFFORD. Thank you very much, Mr. Friedman.

I would propose to my colleagues in view of the witnesses we have to go, we confine ourselves to 10 minutes per member for questions in the first round, if that is agreeable.

Hearing no objection, I will lead off.

Dr. Friedman, based on your studies and those of other scientists, which you have reviewed, is there any doubt in your mind that powerplant emissions cause acid rain?

Mr. **Friedman**. I guess the only way to answer that is: Sulfur dioxide has been strongly implicated with sulfate, and sulfate does enter lakes and can acidify lakes. At the current time, it seems that acid rain is coming partly from utility emissions. The key question is. How much will a change in emissions change acid deposition.

Senator **Stafford**. Is it likely that powerplant emissions in the Midwest cause or contribute to acid rain in the Northeast?

Mr. **Friedman**. Yes; I think it is very likely.

Senator **Stafford**. Do you believe that reducing emissions in the Midwest would probably reduce acid rain in the Northeast?

Mr. **Friedman**. As I mentioned, Mr. Chairman, from my review it seems very likely that this might occur. But there is still uncertainty as to whether that will occur.

Senator **Stafford**. Is the relationship between emissions and acid rain one to one, that is, if emissions are reduced by one-half, can we reasonably expect an improvement in acid rain of the same magnitude?

Mr. **Friedman**. I don't believe I could answer that, Mr. Chairman. That is a very difficult question.

Senator **Stafford**. All right. We have been told that sulfur dioxide emissions in the Midwest could be reduced by 2.5 million tons at very low cost by merely washing coal.

Would you have any opinion as to whether or not this is so, and what the cost would likely be?

Mr. **Friedman**. We have not done coal washing estimates ourselves. Though coal washing is included in our complete model, we have not done separate runs of the costs of coal washing.

There is some potential for coal washing. In some cases there are actual improvements for operation of utilities. I think the 2½ million tons—something like that is a reasonable estimate.

Senator **Stafford**. Thank you very much.

Senator Chafee?

Senator **Chafee**. Thank you, Mr. Chairman.

I am not going to take my full 8 minutes because I see a long list of witnesses here. I will just ask one question of Dr. Friedman as follows: I would like to discuss nitrogen oxide for a minute.

As you know, the automobile industry is suggesting a rollback from the current NO_x standards from 0.1 to 0.2. Presently, in the Northeast, from the figures I have, one-third of the acid rain comes from nitrogen oxide. My question is what, in your judgment, would be the effect if we had this rollback from point 1 to point 2? What would be the effect in the Northeast of acid rain?

Mr. **Friedman**. Well, I am going to answer that a little circuitously, if I may.

There is a great deal of controversy as to the effects of nitrogen oxides—that is, how much of the nitrogen oxides actually end up in lakes, to be able to acidify lakes. Much of the nitrogen that is deposited can be taken up directly by the watershed surrounding the lakes.

During the springtime, the nitrogen oxides may be very important in acidification of the lakes. At other times of the year, they may not actually reach the lakes.

I would like to add another factor in, however. Acid deposition is not the only pollutant that is transported. Another major transported air pollutant is ozone and nitrogen oxide emissions are very frequently linked with ozone levels.

In our study we are also looking at the range of potential damages due to these other transported air pollutants.

Senator **Chafee**. You mean damage to lakes, rivers, and streams, to water bodies?

Mr. **Friedman**. In this case, it would be with ozone damage to forests and damage to crops.

Senator **Chafee**. I am not trying to put words in your mouth. So if you go from point 1 to point 2, don't you think that you are increasing the acid rain and also getting into the ozone problem, which in itself has some deleterious effects on forests, lakes, streams?

Mr. **Friedman**. Just to summarize my probably somewhat confused answer, I think it is very difficult at this point to say whether the increase of nitrogen oxides, or rather the amount of increase due to relaxation of automobile standards, will eventually cause any changes in lake acidification.

I think it is very likely that increases in ozone could have deleterious effects; there could be potential damages from ozone to both crops and forests.

Senator **Chafee**. Thank you, Mr. Chairman.

Senator **Stafford**. I am just going to follow that up with one question.

Are there any health implications in increases in ozone and nitrogen in the atmosphere?

Mr. **Friedman**. In our final report, we will be reviewing some of the health implications of both nitrogen oxides and ozone.

Senator **Stafford**. And would you also be including any health implication of sulphur oxides?

Mr. **Friedman**. Yes; we are also reviewing that literature and trying to revise or examine some of the estimates that are currently available.

Senator **Stafford**. Thank you, very much.

Senator Mitchell?

Senator **Mitchell**. Thank you, Mr. Chairman.

Mr. Friedman, your discussion has focused entirely on the cost of implementing this legislation, and I thank you for it because you made a valuable contribution to the discussion.

In the very closing paragraph, you said that you had not discussed at all the potential benefits of controlling transported air pollutants, and that raises a point that I would like to discuss.

Do you agree that an acid deposition is now exacting a cost in our society?

Mr. **Friedman**. Yes; I would have to agree with that.

Senator **Mitchell**. That there are lakes and bodies of water becoming acidified to the point where they cannot sustain efficient life; there is other damage that is occurring at this time from acid deposition.

Would you agree with that?

Mr. FRIEDMAN. By my review of the literature and the studies we have done, I guess I would have to agree with that.

Senator MITCHELL. So that whether we are talking about the cost of cleaning up or controlling acid deposition, is it fair to conclude that we are not creating a new cost, but that we are simply transferring the cost from one segment of our society which is bearing it to another segment of society?

Mr. FRIEDMAN. Yes, Senator, I think that is a very fair statement. Our final report will essentially be concentrating on those regional distributions of the potential benefits of controlling transported air pollutants and the regional distributions of the potential cost.

Senator MITCHELL. That is right. In other words, whether you talk about the potential benefits, you are talking about in effect eliminating the cost in those areas where it is now being borne?

Mr. FRIEDMAN. That is right.

Senator MITCHELL. And transferring it to another area, is that a fair statement?

Mr. FRIEDMAN. Yes; I think that is.

Senator MITCHELL. And, of course, the problem exists because that segment of our society in a regional or other sense that is bearing the cost presently is not the segment of society that is gaining the benefit from the lack of pollution control. Isn't that a fair statement?

Mr. FRIEDMAN. Yes; I think it is.

Senator MITCHELL. So really in the last analysis, Senator Chaffee's very apt analogy, one fellow is producing garbage but because he doesn't want to pay the garbageman, he throws it over on the other fellow's lawn. So the other fellow has to clean it and he has to bear the cost.

Is that a fair statement?

Mr. FRIEDMAN. I guess the only difference is that it is more like the analogy of finding garbage on the other side, the neighbor having a fairly good idea who threw it over the fence, but not having any idea how he might alter the situation, or whether an action he might take would change what is coming over the fence. I think that is where the uncertainty is.

Senator MITCHELL. Now, with respect to the relative costs. You had described costs ranging from various scenarios from $1.7 to $4.1 billion. But you acknowledged in your statement you only considered a finite list of control alternatives; is that correct?

Mr. FRIEDMAN. Yes; that is true.

Senator MITCHELL. And you did not in your current model analysis consider some of the control strategies that are mentioned in both bills; is that correct?

Mr. FRIEDMAN. That is true.

Senator MITCHELL. And is it a fair statement were these alternative control strategies considered, the cost could be less?

Mr. FRIEDMAN. Most definitely, yes.

Senator MITCHELL. So, the figures you have given are operating as stated candidly and fairly, with a constraint, and did not include all of the control strategies that are included in both bills, Senator

Moynihan's and mine, which both potentially could be used and if utilized would reduce the cost; is that correct?

Mr. **Friedman**. Yes; that is correct.

Senator **Mitchell**. Now, for the basis of comparison, for the purpose of comparison, you have indicated that you are going to have a report on potential benefits.

I would like to ask you whether you are familiar with a study conducted by Dr. Timothy Crocker of the University of Wyoming on the estimated annual benefits of controlling acid deposition in those States east of the Mississippi?

Mr. **Friedman**. Yes; I am.

Senator **Mitchell**. And are you aware of the fact that Dr. Crocker has estimated those benefits to be approximately $5 billion a year?

Mr. **Friedman**. Yes; I am aware that is his estimate.

Senator **Mitchell**. And so if we took, say, the midpoint of your analysis, $1.7 to $4.1, would give us somewhere a little less than $3 billion a year in cost to clean up, and concentrated that with this figure of $5 billion—and understand I am not suggesting this is an absolute figure, then there would be a rather favorable cost benefit ratio, would there not, were this figure to be accurate?

I ask you to assume.

Mr. **Friedman**. Yes, were the figure to be accurate. I guess there is some question as to the reliability of that number.

Senator **Mitchell**. Now, with respect to the current cost that is being borne, could you indicate to us some of the methods in which that cost is being exacted from the regions that are not figured to be bearing some portion of the cost?

Mr. **Friedman**. If I am understanding you correctly, are you asking for some of the damages that have, or some of the damages that potentially could be occurring from acid deposition?

Senator **Moynihan**. Mr. Stockman's fish.

Mr. **Friedman**. Yes; I think I can. I would sort of like to take the opportunity to put my answer into the context of some of the reviews we are currently doing.

We are looking at potential damages to aquatic ecosystems, not only lakes but headwater streams.

We are trying to come up with the total number of lakes and miles of streams that may be at risk in sensitive areas around the United States.

There is some question as to whether damage to forests might be occurring. Most of these damages, if they were to occur, would probably be due to changes within the soil. We are looking at those regions of the country with soils that would be most sensitive to acid inputs.

Senator **Mitchell**. With respect to forests, are you aware of testimony by a representative of the American Paper Institute before this committee that a 1-percent reduction in forest growth, were it to occur, would be, in his words, "An economic catastrophe to the American paper industry"?

Mr. **Friedman**. No; I wasn't.

Senator **Mitchell**. Well, I wish you would take that into your calculations. I will send you a copy of his testimony.

Mr. **Friedman**. Thank you.

Some of the other damages that may be occurring due to acid deposition are damages to manmade materials—buildings, monuments, works of art, and so on. There have been some concerns expressed on health effects. The liturature is very poor on what these potential health effects may be. There may be some water quality changes due to acid deposition for those people who use well water directly. There may be some health effects of aerosol sulfates which are a large component of acid deposition.

Senator MITCHELL. Are you familiar with the testimony of Dr. Orie Loucks before this committee?

Mr. FRIEDMAN. Yes; I am.

Senator MITCHELL. Because you didn't discuss crop damage in your statement. I would like to send you a copy of Dr. Loucks' testimony for your consideration.

Dr. Loucks testified—this is some months ago and my recollection may not be precise. My recollection is he testified damage to crops in this country would occur in the next two decades, that is in the period between 1980 and 2000, in the aggregate amount of approximately $63 billion.

Are you aware of that testimony?

Mr. FRIEDMAN. I believe that was the total instead of annual amounts.

Senator MITCHELL. That is total. In the aggregate, I said over the next two decades of this century in the entire United States?

Mr. FRIEDMAN. May I put those in perspective at least from my opinion? Some of the literature on the effects of acid deposition on crops shows effects both positively and negatively. I don't think we really have good information there. But I would like to add again with respect to effects on crops, we know definitely that another transported air pollutant, ozone, is causing large anounts of damage in the Eastern United States right now.

Senator MITCHELL. On crops?

Mr. FRIEDMAN. On crops, yes.

Senator MITCHELL. And do you have an estimate on those figures?

Mr. FRIEDMAN. Some of the earlier estimates, I believe, and I would have to check on these, are somewhere between 1 and, say, $3 billion per year.

We are currently revising those estimates, reworking them in what we feel is a scientifically more defensible way.

Senator MITCHELL. Does the emission of nitrogen oxide contribute to the ozone problem?

Mr. FRIEDMAN. Yes; Senator, I believe it does.

Senator MITCHELL. Thank you.

Mr. FRIEDMAN. Thank you.

Senator STAFFORD. Thank you, very much, Senator Mitchell.

Senator STAFFORD. Senator Baucus.

Senator BAUCUS. Dr. Friedman, could you tell this committee what studies you are undertaking to try to estimate the means of control? What studies are you now undertaking at OTA?

Mr. FRIEDMAN. Right now we are, if I may review, looking at potential aquatic impacts, potential effects on forests and soils, potential effects on materials and potential effects on health.

Senator BAUCUS. And when will those studies be available?

Mr. **Friedman**. I hope our report will be—our report will be out in the spring of next year.

Senator **Baucus**. Are there draft reports at this time?

Mr. **Friedman**. We do have an interim staff paper that we use, and that we have given to the committee for their information, which I would be happy to make available to you if you don't have a copy.

Senator **Baucus**. To what degree do you anticipate that staff interim report will be changed by the spring?

Mr. **Friedman**. I think it will look very different from what you have. That was an attempt to synthesize the information we had in hand from some earlier work and from literature reviews without incorporating many of the new studies we have undertaken.

Senator **Baucus**. Why will it look different? Your answer assumes knowledge you haven't yet divulged. That is, if you say it is going to be different, you must know something of substance that will require difference.

Mr. **Friedman**. Maybe the bottom lines won't be different, but we will have much more detailed information, such as State-by-State estimates of crop damages from ozone, and regional distributions of the lakes and streams at risk. I am not sure which way it's going to come out, but we will have much more detailed information.

Senator **Baucus**. So you won't have different results, you will just have more comprehensive information. It may be different, you just don't know?

Mr. **Friedman**. That is right.

Senator **Baucus**. It may show a greater benefit from the control of acid deposition and it may show less.

Mr. **Friedman**. Yes; that is true.

Senator **Baucus**. Based upon your tremendous knowledge could you give me your best guess as to how different that spring report will be than the present draft? I am asking you to give your best guess based upon information you now have.

Mr. **Friedman**. I think most of the areas will stay the same. However, some of the statements that we made may be contradicted. In particular, I think some of our attempts to look at materials damage have not been as successful in implementation as we thought they would. We can make the same literature estimates and we will be able to make some new estimates based on the results of our studies.

Senator **Baucus**. Do you agree or disagree with the $5 billion figure reached by Dr. Crocker in his report to the EPA?

Mr. **Friedman**. I guess I have no basis on which to agree or disagree. I think the estimates are very crude.

Senator **Baucus**. They could be higher or could be lower?

Mr. **Friedman**. Yes. I think at this time we cannot put that sort of number on the potential benefits.

Senator **Baucus**. Will you by spring?

Mr. **Friedman**. I really wish I knew. It is unlikely that we can provide dollar estimates, but we are doing our best. I think what we can do at a minimum is to show what some of the potential damages may be. We can't say whether these will occur or will not occur with great certainty, but we can at least put a bound on what these potential damages might be.

Senator **Baucus**. Do you think the problems associated with acid rain are growing, diminishing, or remaining about the same over the last several years, last 5 years? Are the costs greater, or less, or are they leveling off?

Mr. **Friedman**. If I can break that into two pieces. I think it is very difficult to say whether there is any trend in deposition—just what is coming down. I think there is some very reasonable evidence to show that some of the effects are cumulative, and so for each year that we continue, whether the acid deposition levels are the same or slightly varied, I think we are accumulating the effects.

How much that accumulation is, is very difficult to state.

Senator **Baucus**. But you do agree, don't you, a large part, perhaps a major part, certainly a large part of the acid rain problem is due to coal-fired generators?

Mr. **Friedman**. I think that looks very likely.

Senator **Baucus**. And aren't the number of coal-fired generators increasing? Isn't the amount of coal burned increasing over the last several years and projected to increase over the next several years, or is it not?

Mr. **Friedman**. I can provide you with some past emission estimates and I guess———

Senator **Baucus**. Do you know the answer to the question?

Mr. **Friedman**. My examination of the data, given the accuracy of those estimates, indicates that emissions have stayed approximately the same in that region over the past several years.

Senator **Baucus**. I want to add that in the West they are projected to increase. I know some of the studies deal only with the eastern part of the United States. In the West they are projected to increase. I also might add that $5 billion study is based on 1978 data and here it is the end of 1981. And I think there probably is an increase in sulphur emissions in the last several years.

I know you don't have the best data, nobody ever does. But I strongly urge you to look very, very closely at the information you do have, because I think you will be doing everybody a service, industry as well, because I think that we will come up with a better bill the better your figures and the better the figures of everybody else. So you are doing both industry and the environmental community a great service, the more you work very hard and assiduously to get the best data.

Mr. **Friedman**. We are trying.

Senator **Baucus**. Thank you, Mr. Chairman.

Senator **Stafford**. Thank you, Senator Baucus.

Senator Moynihan.

Senator **Moynihan**. Dr. Friedman, that was superb testimony and also very elegant research. That is not easily done, and you know you are working in an area where you don't know all you want to know. You never know all you want to. You have been cautious in what you said to us. I would like to urge, however, that you do look at the question of the benefit side of a cost-benefit analysis, the question of who is paying the cost that would be saved by this kind of event.

You do agree that the Clean Air Act as it now exists does not adequately address this question of interstate transport? That is the first fact I think we have to deal with.

Mr. **FRIEDMAN**. I think that is very true, yes.

Senator **MOYNIHAN**. In part because we are just learning about this. It is newly encountered as a phenomenon, however old it may be. And there is really argument on that score.

But the National Research Council has certainly come out with a very emphatic statement about the economic risks as well as the sort of biosphere risks here. What would you expect to find in the way of economic costs now incurred that you could quantify?

You see, you are going to be followed by someone from the administration who said, "Well, we don't know enough." And how they can know so much about some things and so little about others is what continually amazes me. They know exactly what will be the returns from a 25-percent reduction in income tax to the exact nickel, but they don't know enough here. If it costs money you can't do it.

What would you look to in terms of economic benefits here because we are talking about a 4-percent increase in residential electric bills, and if we don't say it they will say it.

Mr. **FRIEDMAN**. I guess the only way I can fairly answer that, from my look at the situation right now and some of our preliminary work, is to say that many of the areas are difficult to put dollar figures on. It seems that given the accurary of our estimates, it is very likely to be in the same "ballpark" as the cost figures.

Senator **MOYNIHAN**. So you think we can probably end up saying this is a wash and what it does is correctly allocate cost to people who are getting the benefit of the power generated out to pay the cost in the pollution consequences, or rather should not get a benefit by imposing costs on someone else.

Mr. **FRIEDMAN**. I guess I was going to qualify that. I don't know if I could say it is a wash. I guess what I wanted to say is we can't really tell what the benefit-cost ratio should be at this time—maybe somewhat higher, maybe somewhat lower. I think there is a reasonable probability——

Senator **MOYNIHAN**. Well, you are going to try.

Mr. **FRIEDMAN**. Yes.

Senator **MOYNIHAN**. You have done a very nice piece of work here for which we are much in your debt. There is a principle of equity. You must not poison your water for your neighbor downstream. There is a common law perception of that that goes back. We are in a position of identifying something no one has, because it ends up you thought rain came from heaven and in fact it comes from Ohio.

Mr. Chairman, if I could thank Dr. Friedman. You are aware of the atmospheric modeling group that United States-Canadian scientists are working on. Let me put the question to you. Wouldn't you think it would be a good thing to ask them to analyze this legislation in terms of probable consequences in deposition? I think that model is far enough advanced to do that at this point.

Mr. **FRIEDMAN**. Well, I guess I would have to answer that the models that that group are using would give us estimates of loadings if the assumptions of the atmospheric chemistry and other assumptions included in the model are correct. It would be a bound on some of those estimates.

Senator **Moynihan**. You mean a probability bound?

Mr. **Friedman**. It would essentially say that if the assumptions were correct, if the atmospheric chemistry occurred as is included in the model, this is what the deposition would look like. It would tell you that if the resulting deposition reductions were not up to what you thought were necessary, that maybe the emissions reductions figure that you chose should be re-evaluated.

Senator **Moynihan**. You would know more after you went through the exercise than you did before, wouldn't you? You might know some things that aren't so about the risk?

Mr. **Friedman**. That is right. You couldn't say that what the model says was true, but at least you would have an idea whether under those assumptions, what you were doing met your expectation.

Senator **Moynihan**. Could I, on that ground say, I wonder, Mr. Chairman, if we couldn't ask our staff or OTA to ask the United States-Canadian group if they won't put these various propositions through the model and see what comes out and see if they give us any indication where we can maximize. I mean there may be some efforts that are too small to be worth it or too large on the margin to be worth it. What we are talking about here at minimum, we are going to be talking about marginal costs?

Mr. **Friedman**. I am sorry, I missed that.

Senator **Moynihan**. At minimum we are going to be discussing how much extra does it cost to have the extra unit, how many units of cost per unit of diminished loading. What you see in the two bills you analyzed, and Senator Mitchell and I put in two bills of slightly different concept, but basically different numbers.

Mr. **Friedman**. That is right.

Senator **Moynihan**. And there is a whole range of those numbers. So I would hope, Mr. Chairman, we might get the United States-Canadian group involved and see what we can learn. Thank you very much, Dr. Friedman.

Senator **Mitchell**. Mr. Chairman, would the Senator yield to a followup in those terms?

Senator **Stafford**. Sure.

Senator **Mitchell**. In discussing cost-benefit ratio, you started a sentence that you said you think there is a reasonable probability and then did not complete the sentence. Were you going to say that ultimate benefit, the benefit will approximate the cost?

Mr. **Friedman**. I guess as far as I could say, there is a reasonable probability that it could go either way.

Senator **Mitchell**. When I lectured, on cross examination, I always told my students never ask a question unless you know what the answer is going to be.

Mr. **Friedman**. Yes, but the equity problems remain.

Senator **Stafford**. Thank you very much.

Senator Hart, did you have any questions?

Senator **Hart**. No.

Senator **Stafford**. Senator Gorton?

Senator **Gorton**. No questions.

Senator **Stafford**. In that case, Dr. Friedman, we are very grateful to you for helping the committee. Thank you.

I would remind my colleagues we still have a major witness and three panels to go. The Chair's intent would be to keep the meeting going until we complete or until 1 o'clock.

Our next witness will be Kathleen Bennett. She is Assistant Administrator for Air, Noise, and Radiation, U.S. Environmental Protection Agency in Washington.

Mrs. Bennett, we welcome you on behalf of the committee. We have your written statement which will be in the record in full, and we would invite you to summarize it any way you see fit.

STATEMENT OF KATHLEEN M. BENNETT, ASSISTANT ADMINISTRATOR FOR AIR, NOISE, AND RADIATION, ENVIRONMENTAL PROTECTION AGENCY, ACCOMPANIED BY PAUL STOLPMAN, DIRECTOR, OFFICE OF POLICY ANALYSIS, EPA

Mrs. **Bennett**. Thank you, Mr. Chairman and I shall attempt to summarize.

Good morning, Mr. Chairman and member of the subcommittee, I am Kathleen M. Bennett, Assistant Administrator for Air, Noise, and Radiation of the U.S. Environmental Protection Agency.

Accompanying me is Mr. Paul Stolpman who is Director of our Office of Policy Analysis.

I am pleased to appear before you today to discuss the Agency's views on transboundary pollutant transport and acid deposition, in particular. Both have become issues of increasing global interest in recent years, and matters of concern to the administration and to Congress.

I will skip some of the background information.

"Acid deposition" is a general term for the deposition of acidic materials, whether wet or dry, from the air onto the surface of the Earth or upon structures or objects. Neither acid deposition itself nor the terminology by which we describe it is of recent origin, but the scientific study of acid deposition as a separate field is scarcely more than a decade old, and our understanding has improved considerably in the last 5 years.

Acid deposition exists, and varying effects do occur, but there is considerable debate over the circumstances of its formation and the feasibility of potential controls. Scientists may see the same data on acid deposition and circumstantially associated pollutant emissions and reach quite different conclusions.

Currently, we do know something about the emissions of oxides of sulfur and nitrogen which can be the precursors of acid deposition. We know that emissions tend to be highly interactive, and that multiple emissions must be considered simultaneously. For all that is known about acid deposition, a number of major uncertainties in our current thinking remain to be resolved.

One uncertainty has been the pH level at which precipitation should be considered "acid." The conventional definition is based on pure water saturated with atmospheric carbon dioxide. It has a pH of 5.6, which is, therefore, the theoretical level of "normal" rainfall. Naturally occurring precipitation may be considerably more or considerably less acidic.

In addition, although oxides of sulfur and nitrogen are precursors of acid deposition, the transformation processes are still not understood. No clear evidence is yet available which can explain or predict accurately how precursors are transformed or why the observed variations occur.

Yet another uncertainty exists with regard to the transport and distribution of precursor emissions Remote regions of the globe have rains with a low pH, as do Hawaii and Alaska, and there is controversy over the role that localized emission sources may play. To resolve such controversies, both better data and more accurate modeling techniques are necessary.

Additional uncertainties for which we need better data include the relative impact of local sources as compared to more distant sources; the role of other photochemical pollutants and how they affect acidity levels; and the relative importance of the various effects from acid deposition—that is, aquatics, forests, materials, and so forth.

Any administration action must be based on a reasonable degree of certainty that it will, in fact, accomplish its intended purpose. The American people have the right to expect that their Government will not impose an additional multibillion dollar program without first determining with some assurance that the intended environmental benefits will be achieved.

In this case, quick and simple solutions are unlikely. Given the length of time it has taken to recognize the magnitude and complexity of the problem and the many fundamental questions that remain to be answered, Congress wisely authorized a comprehensive research program.

Currently, in an effort to reduce uncertainties so that meaningful and effective program options can be considered, EPA is working on a number of projects.

EPA alone has committed more than $9 million in fiscal year 1982 just to its research efforts on acid deposition; other Federal efforts will bring the total to more than $18 million.

The three major areas of uncertainty toward which EPA's portion of the research program is directed are as follows:

One, transport, transformation, and deposition processes;

Two, effects of acid deposition; and

Three, assessments and policy studies.

I have attached to my statement an inventory of the Agency's major research efforts in the acid deposition area.

In 1980, Congress passed the Acid Precipitation Act. It established an interagency acid precipitation task force which is to prepare a 10-year comprehensive research plan to identify the causes and effects of acid deposition. Congress directed that an annual report be submitted "which shall detail the progress of the research program under this subtitle and which shall contain such recommendations as are developed."

The comprehensive research plan, entitled the "National Acid Precipitation Assessment Plan," is currently being updated to incorporate public comments.

Furthermore, the results of research from all sources, public and private, are compiled and evaluated in assessments that provide research support for regulatory decisionmaking.

ANTICIPATED RESEARCH RESULTS

Over the next 3 to 5 years, we anticipate that many ambiguities and uncertainties will be reduced. Specifically, we expect to have the following information:

Additional studies of historical lake, stream, and reservoir data.

The results of five models for predicting sulfate deposition on an annual basis.

Status reports on acid deposition effects on agricultural crops.

A new report on the role of clouds and storm fronts in formulating and scavenging acids in the atmosphere.

The results of pilot tests and a completed demonstration of new combustion processes for controlling oxides of nitrogen and sulfur dioxide at significantly reduced costs.

A summary report on the impacts of acid deposition on materials.

Additional results from Sweden on forest productivity.

A progress report by the National Oceanic and Atmospheric Administration on acid rain in remote locations.

An aquatic model for predicting the rate of acidification occurring in lakes.

A series of second-generation models for predicting the transport and deposition of sulfur and nitrogen over long distances.

Field studies validating laboratory experiments of the effects of acid deposition on selected major crops.

GLOBAL TRANSBOUNDARY AIR POLLUTION ACTIVITIES

Because transboundary air pollution is a global concern, EPA has been consulting with other interested countries, particularly Canada, and will continue to do so.

With the August 5, 1980, memorandum of intent on transboundary air pollution, Canada and the United States agreed to begin cooperative steps to deal with transboundary air pollution and to develop a bilateral agreement. Formal negotiations began in June and are scheduled to resume next week.

Within this structure, work groups are preparing the technical summaries of currently available information. The work groups are comprised of representatives from EPA; the Departments of State, Agriculture, Interior, and Energy; the Council on Environmental Quality; the National Oceanic and Atmospheric Administration; and other agencies as well as representatives from corresponding Canadian departments. Interim work group reports currently under review and revision are due to be completed early next year.

SENATE AMENDMENTS ADDRESSSING LONG-RANGE TRANSPORT

The amendments proposed by Senators Mitchell, Moynihan, and Dodd each provide mechanisms for dealing with acid deposition or, more broadly, the interstate transport of air pollutants. At your request I will discuss each of these briefly.

Although the Mitchell and Moynihan bills are based on different equations, each basically calls for substantial reductions in SO_2 emissions over the next decade. In general, the impact of these reductions would fall primarily on those few States whose emissions sources rely most heavily on locally available high sulfur coals. Thus, some States will experience large—perhaps over 10 percent—increases in their utility bills while many other States will be virtually unaffected.

This uneven impact could increase the tension already evident between States and make it more difficult to secure State cooperation in developing a cost-effective control strategy for acid deposition.

Although the regional impact of the proposed bills is obvious, EPA has not had an opportunity to analyze the consequences of these bills in detail. Therefore, I am not prepared to address the specific effects of the types of measures mandated in these bills. I would like to reiterate that the scientific uncertainty surrounding the causes and effects of acid deposition at this time demands that we proceed cautiously and avoid premature action, unless we have some confidence that the intended environmental benefits would be produced.

Since the passage of the Clean Air Act of 1970, it is estimated that our Nation has spent approximately $150 billion on air pollution control. Those expenditures have been driven by our attempts to meet the health and welfare requirements of the act. We estimate that the approach proposed in these bills could increase expenditures by roughly $2 to $4 billion per year. Further, the implementation scheme for both bills is a little unclear and could be exceedingly difficult to administer.

These bills involve a radical new concept in pollution control based on a total loadings approach. Such an approach would represent a sweeping departure from our current national program which is based on protection of health and welfare through control of local ambient air quality levels. Before proceeding with such a dramatic and expensive overhaul of the underpinnings of our air cleanup efforts, we must better understand the need for a total loading approach and what the impact might be.

The amendments to sections 110(a)(2)(E) and 126 proposed by Senator Dodd are designed to improve the decisionmaking process on interstate petitions under section 126. While we support the goal and general approach of this bill, we are concerned about some of its specific provisions.

The most troubling aspect of the bill is the new penalty provision which requires the court to assess a penalty of $100,000 against the United States, if the Administrator fails to act on a petition within 120 days. I am deeply disturbed by the concept that the general taxpaying public would be punished for the Agency's failure to act within the short statutory period. This provision could serve as an incentive for a State to complicate the process—at the expense of taxpayers in other States. This provision could divert the attention and resources of the Agency from other statutorily mandated responsibilities. Delays already result from many factors, including the demands of meeting other statutory obligations, the complexity of interstate pollution questions, and the vagueness of the current statutory guidelines.

Currently, the Agency is seeking to reduce the complexities and uncertainties which have inhibited the implementation of section 126. To improve the Agency's ability to evaluate petitions, the

Agency announced at a section 126 hearing in June 1981 that three showings should be made as part of any section 126 petition. These are a demonstration of the scope of the area subject to the petition, a demonstration that achievement of the national standards or measures necessary to prevent significant deterioration or protect visibility is prevented by named out-of-State sources, and an indication that sources within the petitioning State, which affect the area subject to the petition, have adequate pollution controls. The Agency is developing further guidance aimed at improving and accelerating its review of section 126 petitions.

The Dodd bill adds to section 110(a)(2)(E) a new prohibition on pollutants from one State that "contribute to pollution which may reasonably be anticipated to endanger public health or welfare in any other State." This new basis for filing an interstate petition is similar to language now in section 115, concerning international air pollution, and suffers from the same difficulty as that language: It provides for control of pollutants for which no national ambient air quality standard has been set.

In essence, it grants the Administrator broad discretion to require potentially costly emission reductions for pollution control, without provision for the type of scientific review and procedural protection provided in the national standard-setting process under sections 108 and 109.

We readily support the Dodd bill's concept of including a list of criteria which the Administrator must consider in acting on section 126 petitions. The criteria listed in the bill, however—such as total loadings of any pollutant from all sources in the area—are very difficult to quantify. This requirement places a heavy burden on the Administrator, the petitioning State, or both parties, depending who is required to provide the information. The bill does not indicate which party must provide the information.

Another problem is the bill's prohibition against sole reliance on only modeling or monitoring previously approved by the Administrator. This means the Agency will have to devote considerable time and resources to evaluating new studies and modeling techniques.

A thorough assessment of such methods, which is necessary if they are to provide the basis for any action, cannot be accomplished within the 120-day period provided by the bill. Aside from the time constraints, we believe it would be unwise to evaluate new modeling or monitoring approaches in the context of individual section 126 petitions. The factual background of an individual petition could distort the Agency's review of a particular method, especially if the Agency is faced with severe penalties for failure to act swiftly.

In summary then, acid deposition is a concern of many Americans, one shared by the Congress, and by the administration. The depth of our concern about acid deposition should be reflected in public policies that are based on sound science.

As we have indicated, there are major uncertainties in many critical areas, particularly about the transportation and transformation of possible precursor emissions into acid deposition, the effects, and the policy implications of acid deposition. In passing the Acid Precipitation Act of 1980, Congress itself established a comprehensive intergovernmental and interdepartmental research plan so that the complexity of acid precipitation could be more fully addressed.

Without such a firm foundation *on which to base our decisions* on whether controls are necessary, in what areas and to what degree, any regulatory action at this time would involve guessing.

In view of the many fundamental scientific uncertainties; the possible substantial cost burden of additional controls; the extensive congressional involvement, including the 10-year directive to investigate the problem; and the fact that current research is expected to provide us with better data and guidance, we look forward to fulfilling the perceptive, far-reaching and multidisciplined approach of Congress, as embodies 16 months ago in title VII of the Energy Security Act.

This concludes my prepared statement. I would be happy to respond to any questions you may have.

Senator STAFFORD. Thank you very much, Mrs. Bennett.

The Chair doesn't like to do so, but again we will have to remind our members that we still have three important panels to go, and in light of that the Chair is going to reserve the right of all members of the committee, including those who aren't here, to submit questions in writing to the witnesses, unless there is objection to that procedure, as an attempt to save some time.

Having said that, the Chair will go immediately to Senator Mitchell for questions.

Senator MITCHELL. Mrs. Bennett, you said in your statement that our concern should be reflected in public policies that are based on sound science. Do you regard the National Academy of Science as a source of sound science?

Mrs. BENNETT. I do, Senator, and their report on the subject is very important. However, as you read through it, particularly in the chapters toward the middle and back, there is strong indication that even the scientists themselves that were on that panel did have some questions themselves about some of the very fundamental questions I have outlined in my testimony.

Senator MITCHELL. No question about the fact that they have questions, as we all do. But is there any doubt in your mind they have made a very specific and unambiguous recommendation that can be translated to say we must act now?

Mrs. BENNETT. Their recommendation was to act now, to do something, but they were not very specific as to what to do.

Senator MITCHELL. But you have rejected their recommendation when you say we should study the problem for 3 to 5 more years.

Mrs. BENNETT. I think that is very important. We are doing that at the direction of the Congress and we believe the questions that our research is aimed at answering will help us a great deal in knowing what is the best course of action.

Senator MITCHELL. Well, let me read to you, just in case, so there is no misunderstanding. Their report says,

> Options presently available. Only the control of emissions of sulphor and nitrogen oxide can significantly reduce the rate of deterioration to sensitive fresh water ecosystems.

Then it goes on, and I won't read the whole thing.

Control of SO_2 from new electrical generating plants alone would be insufficient to accomplish this, and thus restrictions on older plants must be considered.

I just think that you have in fact rejected the National Academy of Sciences, and I want to make the point that we all agree that we must base our policies on sound science. And I don't think there is any disagreement on the fact that there is no scientific body in this country that has greater respect, that is more impartial, and whose advice we should heed than the National Academy of Sciences. And they have made a recommendation which you personally though the administration have chosen to reject, and I think that is a significant point.

The only possibility is when you say we ought to base the decision on sound science, it implies those of us who favor action now are basing our decision on something other than sound science, and that is not so.

Mrs. BENNETT. The areas of research being directed at acid deposition are to include fundamental questions the National Academy shares with us. What exactly are the pollutants of concern? True, sulfur dioxide and nitrogen oxide seem to be the most obvious pollutants of concern. But the question is the ratio of the two, whether it must be both, or one. What precisely is the role of ozone, hydrocarbons, and so on. All of these remain. questions. What are the sources of those pollutants that are of concern? Is it local sources? Is it medium range distance sources? Is it far away sources? What precisely is the transformation of the upper atmosphere or is the pollutant of concern emitted close at hand?

Senator MITCHELL. Let me just remind you say in your statement, in other words, "It is widely recognized that pollutants can be carried in air masses across jurisdictional boundaries to cause transboundary and interstate air pollution." Those are your words.

Mrs. BENNETT. True, but it doesn't tell me what effect they have downwind or what effect they have while they are in the upper atmosphere, or is it more important when emitted close at hand.

Senator MITCHELL. But you recognize there is transboundary air pollution?

Mrs. BENNETT. Certainly, there is no question there is, that doesn't tell us if they are causing an acid rain problem.

Senator MITCHELL. It may not tell you that but it tells a lot of others.

Now when you refer to Senator Moynihan's and my bill representing "a sweeping departure from the current national program which is based on protection of health and welfare through control of local ambient air quality levels," if you agree that there is a problem of transboundary air pollution, then you must conclude, as we have concluded, that some departure from our current program is necessary. It may be sweeping only in the sense that it is a recognition, is it not, the existing statutory approach is inadequate to deal with the transboundary problem, isn't that a fair conclusion?

Mrs. BENNETT. There are problems with the way the current act addresses interstate and international air pollution. I don't dispute for one moment air pollution is very recalcitrant and refuses to obey State or international boundaries.

The structure we have in the act today, there are some needs there for clarification and for at least a more clear decisionmaking criteria as to how we would go about dealing with these problems. However, the current act, our Nation's current approach to air quality is based around, again, strong signs determining which pollutants cause affect on health or welfare, standards for those, and State plans under which those standards will be achieved. The approach that your bills would recommend would have a shift which would serve, I assume, as kind of a superstructure over that, and I don't feel comfortable telling the American people now that I could safely guarantee it would cure the problem at which this seems to be aimed, namely, the acid deposition problem.

Senator MITCHELL. You talked about your commitment to do additional research on acid deposition. You said other Federal efforts will bring the totals to more than $18 million. Are you aware of the fact the National Oceanic and Atmospheric Administration is contributing importantly to that effort through its atmospheric modeling and monitoring?

Mrs. BENNETT. Yes.

Senator MITCHELL. You include that as part of the administration effort to deal with this problem?

Mrs. BENNETT. Yes, sir.

Senator MITCHELL. Are you aware in the administration's budget request it asks all funds to do atmospheric modeling and monitoring on the problem of acid rain were requested to be eliminated from the budget of the National Oceanic and Atmospheric Administration?

Mrs. BENNETT. Are you addressing fiscal year 1983?

Senator MITCHELL. Yes.

Mrs. BENNETT. I am not aware of the details of the NOAA budget.

Senator MITCHELL. Well, I give them to you. I think it is important that we recognize and talk about the administration's commitment to the problem. As you have acknowledged, the atmospheric modeling and monitoring by the National Oceanic and Atmospheric Administration is an important part of the effort, and its fiscal year 1982 budget prior to the reduction, it provided nearly $2 million, which is a large part of the totals you have suggested, and the administration requested that be completely eliminated?

Mrs. BENNETT. As I say, I am not aware of their totals. $3.1 million will be expended in that area by EPA.

Senator MITCHELL. Only because the administration effort to eliminate that was rejected. All I am saying is that——

Mrs. BENNETT. Excuse me, Senator, there was no request to eliminate those funds from EPA.

Senator MITCHELL. No; the atmospheric modeling and monitoring by NOAA were requested by the administration to be eliminated, something which you have acknowledged is an important part of the effort. What I am saying is those of us who are deeply concerned about the problem question the good faith of the administration, in saying if we really want to study this problem, we really want to do something about it, and then at the same time requesting that an important part of the program, of the study program, you yourself acknowledge an important part, atmospheric modeling and monitoring be eliminated and that it not be done.

Mrs. BENNETT. As I have noted, our own agency will be expending $3.1 million in that area, so the subject itself will not go unaddressed.

Senator MITCHELL. But this other activity is an important part as well. The two are not mutually exclusive.

I don't want to take too much time. I have a number of other questions which I will ask. I just want to say I do question the administration's good faith in this area. I really do. I hope I am wrong. I hope you will proceed in good faith. I don't know at what point you feel there is going to be enough scientific evidence to act. We already have the National Commission on Air Quality, which Senator was very active with, they did a very thorough analysis. They concluded action should be taken. The National Academy of Sciences, which you acknowledge is the most prestigious scientific body in the country, did a very thorough analysis. They concluded action must be taken.

How many more people are going to have to come in; how many more studies are going to have to be completed before the administration is prepared to say we will do something about the problem?

Mrs. BENNETT. Those studies said we should do something, but were less specific about what. We are faced with implementing the congressional directive to answer those very questions. We don't believe you have to wait until you know everything before you do something, but we have to do more than we know.

Senator MITCHELL. I would be happy if you would agree something needs to be done. We don't agree with your approach. As I said in my opening statement, I don't suggest my bill is perfect. Clearly far from it. And I would like to see some constructive suggestions from the administration, rather than just saying, well, we have just got to study the problem more. That is my only point.

Senator STAFFORD. Thank you very much, Senator Mitchell.

Senator Baucus.

Senator BAUCUS. Thank you, Mr. Chairman.

Mrs. Bennett, do you think there is an acid rain problem in the country?

Mrs. BENNETT. There is at the very least a very serious question.

Senator BAUCUS. Do you think the benefits for acid deposition control are also significant?

Mrs. BENNETT. Ironically, the scientists tell us the least about the areas where the economics can tell us——

Senator BAUCUS. Are you familiar with Dr. Crocker's report to you?

Mrs. BENNETT. Yes, and that is precisely the one I am referring to. His report listed four areas of possible economic effects, and they are aquatic ecosystems, agricultural ecosystems, forestry ecosystems and materials. Mr. Crocker himself points out we seem to know the least about the area where the benefits seem to be the most. And the converse. He also has qualified his statement by saying his rank ordering seems to be about right, again, it doesn't tell you very much about the science of how you address those problems.

Senator BAUCUS. He does come up with $5 billion based on 1978 data, is that correct?

Mrs. BENNETT. Yes, but with a lot of qualifiers.

Senator BAUCUS. But that is his best estimate based on qualifiers. Is it possible the estimate could be higher with more——

Mr. STOLPMAN. If I could maybe read a quote from Dr. Crocker.

Senator BAUCUS. I am sorry, could you identify yourself.

Mr. STOLPMAN. Paul Stolpman from EPA. He went on to say in some of his analysis that:

> We therefore have substantially more confidence in the rank ordering by sector of the current annual benefits than we do in our estimates of absolute magnitude of these benefits.

That is Dr. Crocker himself. I think what Dr. Crocker has done is he has tried to create a methodology for studying benefits. Even he admits you shouldn't use the absolute numbers generated by that methodology to do anything other than determine where the highest economic benefit might be. That happens to fall in the materials area and forest ecosystems area which we——

Senator BAUCUS. Nevertheless, he did come up with a $5 billion figure based on 1978 data?

Mr. STOLPMAN. That is true, of which only $250 million is aquatic, where we know the most.

Senator BAUCUS. Let me ask Mrs. Bennett another question. Do you generally agree with Mr. Chafee's analogy, a neighbor should pay for and clean up his garbage rather than dumping it on his neighbor's lawn?

Mrs. BENNETT. Yes. I was also rather interested in Mr. Friedman's reply. If you are having that kind of problem, it doesn't tell you what to do. It doesn't tell you to build a taller fence or post a guard.

Senator BAUCUS. You do believe the approach suggested by the analogy?

Mrs. BENNETT. If that in fact is what is going on.

Senator BAUCUS. The person causing the damage should generally pay for it even though the cost may be passed on, certainly in the first instance that person should pay for it in a reasonable way?

Mrs. BENNETT. In that regard I think we have a record we can be proud of in this country. In what we have done in controlling these pollutants.

Senator BAUCUS. You say the EPA budget for your continued studies—I must say I was a bit struck with the long list of studies you are undertaking—is about $3.1 million. Is that correct?

Mrs. BENNETT. It is about $9 million at EPA. The $3.1 million is atmospheric modeling.

Senator BAUCUS. At least for 1982?

Mrs. BENNETT. Yes, sir.

Senator BAUCUS. And Administrator Gorsuch's draft, her actual submission to OMB for fiscal year 1983?

Mrs. BENNETT. The figures for fiscal 1983 are still very much a subject of discussion between the Agency and OMB and OMB and the President.

Senator BAUCUS. I understand they are in discussion. My question to you is what is the figure?

Mrs. BENNETT. Nothing is final at this point.

Senator BAUCUS. I know it is not. It won't be final until Congress acts next year, and there will be lots of discussion. My question is what is the figure that will in fact be discussed now and later?

Mrs. BENNETT. It would not be appropriate for me to speculate.

Senator BAUCUS. Is it higher or lower?

Mrs. BENNETT. I can say there is a high level of commitment to continue the acid rain research program, and there was an increase over fiscal year 1981 to fiscal year 1982.

Senator BAUCUS. Assuming it is an additional 20 percent cut, and at least what the submission said, 20 percent cut generally for the EPA budget, and assuming another 12 percent cut on top of the previous 12 percent cut for fiscal year 1982, based on your knowledge of your department, what would be the personnel cut result, assuming that two cuts of 12 percent for 1982 plus an additional 20 percent for 1983? I am not saying that is it. I am saying if it does happen, based upon your knowledge of your shop, what would the cut in personnel be?

Mrs. BENNETT. Senator, it would be extremely difficult to speculate for several reasons. First, as you correctly note, nobody has any idea whether that will happen. Second, a number of various exercises have been undertaken at our agency as well as from other agencies to figure out the consequences of going one way or another way. As we know, nothing is final until it is final, and final in this instance is not then until the Congress acts on it.

Third, whenever a percentage might be arrived at, it is very difficult to speculate in advance as to what that might mean to people, because cuts could be taken in just lots of different ways and programs. But if you distribute equally well across the Government——

Senator BAUCUS. And if it turns out that amount set aside for the air modeling is cut, and if it turns out that your particular operation is cut, too, will that lengthen the time that it will take for EPA to complete its studies?

Mrs. BENNETT. Again, Senator, you are asking me to speculate to a great deal of detail on——

Senator BAUCUS. I am not asking in detail. I am asking a general question.

Mrs. BENNETT. I really cannot speculate. For example, you might say this study got cut to zero. The reason might be you completed the study.

Senator BAUCUS. You say in your statement it will take 3 to 5 years.

Mrs. BENNETT. To know all the things I identified. Some might last for 4 years.

Senator BAUCUS. My question is, Will it take a longer period of time, will it take more than 3 to 5 years if in fact your operation is cut by let's say 30 percent? Will it take you longer?

Mrs. BENNETT. Some studies lend themselves to being solved faster with a lot of dollars spent on them. Other studies are subject to longer times. For example, in forestry studies you can't hurry them along. On the other hand if you are studying root hairs, those are things that change from year to year. I give this as an illustration. It is very hard to answer in general as to what the length of time will do to one study.

Senator BAUCUS. Very frankly, Mrs. Bennett, I am giving you the opportunity to show your good faith, as Senator Mitchell did. Frankly, I don't see it. I hear lots of long evasive answers. In your statement you are listing all these reports and studies you want to undertake. I hear reports in EPA, none of which have been refuted by EPA. It is just we don't want to talk about it. I want to give you an opportunity to show your bona fides. I must confess I don't feel it. Even reading between the lines I don't see it. And reading between the lines, frankly, I must regretfully tell you I suspect the opposite.

I think you are making a big mistake. It is very short term and very myopic. I think you are doing, not only the country a disservice, but I think you are doing the EPA and administration a disservice. I frankly urge you reconsider, you and others in the EPA and administration, and get on with the show and let's solve this acid rain problem immediately. I thought this administration stands for efficiency and quick decisionmaking. I find the opposite. It is delay. It is obfuscating. It is the most classic form of problems we have in the bureaucracy that we have always had, but I think for different reasons, and not because the bureaucracy is too timid to make the decision, but rather because the bureaucracy doesn't want to make the decision, it wants to delay. It wants to prevent the Congress in this case from acting.

I think if you think more clearly and critically you are going to reach a different conclusion.

Mrs. BENNETT. Senator, I have tried to assure you of our strong commitment to solving this problem. I have pointed out we have had an increase in EPA in dollars devoted to acid rain research in the present fiscal year. In fiscal year 1981 it was $7.2 million; today it is $9.1 million, an increase at a time when other areas were having to be scaled back.

Senator BAUCUS. I hope when the budget comes out next January we see an increase also, not a big decrease. When we see that January budget, then we will know whether you are in fact obfuscating or you, for very legitimate reasons, feel it is inappropriate. We will see some time.

Mrs. BENNETT. Thank you, Senator.

Senator HART. I take note of the fact the vote is on, the Chair will return momentarily. In the meantime, Mrs. Bennett, let me observe in the 16-page statement you have delivered I find only two references to damage caused by acid rain. One is on page 2. You said, "Damage could possibly result from dry and wet acid deposition of acidic compounds, heavy metals and toxic organic substances."

I underscored "could." On page 3 you said, "Studies of fish populations in the Adirondacks and Sudbury, Ontario, lakes stimulated North American interest." Not a particularly strong assessment of the damage.

Let me point out to you that the National Commission on Air Quality concluded:

Increased acidity has resulted in more than 100 fishless lakes in the Adirondacks area of New York, more than 140 fishless lakes in the Canadian province of Ontario, and more than 13,000 fishless lakes in Sweden.

Are those two references in your statement all that the administration is prepared to say to date about damage from acid rain?

Mrs. BENNETT. No, sir, our interest was in keeping our statement to manageable length. We are aware where damage is occurring. We have the clearest examples and most easily measured and documented are those occurring aquatically. The fishless lakes in the Adirondacks and also some of heavy metals migration in New England. Other areas include materials, possibly forest, possibly agricultural effects.

These latter two are where we don't know as much as we would-like to, toward which EPA research is devoted.

Senator HART. You don't have anything that would quarrel with the qualitative analysis of the Commission?

Mrs. BENNETT. No.

Senator HART. Well, given that, I would just add to the evidence by some of my colleagues about the degree of seriousness which EPA presently takes this problem, understanding the need for additional data and study. I think what all of us would like to see is a little more sense of urgency on EPA's part, given those facts, about coming up with the problem, not hesitancy about coming up with the wrong solution and wanting to avoid taking the wrong tack.

But the sense there is a problem that needs to be solved and your agency is going to do it.

Mrs. BENNETT. If I may note in that connection, Senator, the principles that the President approved and the administrator announced in the beginning of August under which we hope review of the Clean Air Act can be accomplished, included acid rain research among them. In fact the President has called for acceleration of this research. We are into the discussion now I had with Senator Baucus as to our commitment with carrying this out. Congress has given us a 10-year, $100 million program. We think it can be done more cheaply.

We think we will have answers more quickly. We think the next 3 to 5 years we will have important findings.

Senator HART. I won't rely too heavily on the deadlines set a few years ago. I think we want to move faster.

Mrs. BENNETT. The act was passed in 1980.

Senator HART. The committee will stand in brief recess until the return of the Chair.

[A brief recess was taken.]

Senator STAFFORD. The committee will please come to order. Mrs. Bennett, I understand from staff people here representing the Senators that they have finished their interrogation as far as you are concerned.

There may be some questions in writing from members which we would appreciate your responding to as soon as you conveniently can, and I will express the thanks of the committee to you for coming up and assisting us.

Mrs. BENNETT. Thank you, very much, Mr. Chairman.

Senator **Stafford.** I would ask our guests to refrain from conversation in the hearing room.

In view of the time constraints that we are running into and the fact the Senate is now in session, I am going to ask the fifth and sixth panels if they would mind combining and sharply reducing their oral presentation, because if we don't compress things at this point, we will find ourselves in trouble with the Senate itself.

The Chair would ask Hon. James E. Tierney, attorney general of Maine; Hon. Robert Flacke, commissioner, Department of Environmental Conservation, New York; Dr. John Holmes, chief, Research Division, California Air Resources Board; Mr. William Hinkley, environmental administrator, Department of Environmental Regulation, Tallahassee, Fla., Mr. Robert Martini—that is a word familiar to the chairman—task force leader, Department of Natural Resources, Rhinelander, Wisc., and Robert Arnott, assistant director, Colorado Department of Health, Denver, Colo.

If you would all join at the witness table.

STATEMENTS OF HON. ROBERT FLACKE, COMMISSIONER, DEPARTMENT OF ENVIRONMENTAL CONSERVATION, ALBANY, N.Y.; HON. JAMES E. TIERNEY, ATTORNEY GENERAL, AUGUSTA, MAINE; DR. JOHN R. HOLMES, CHIEF, RESEARCH DIVISION, CALIFORNIA AIR RESOURCES BOARD, SACRAMENTO, CALIF.; WILLIAM HINKLEY, ENVIRONMENTAL ADMINISTRATOR, DEPARTMENT OF ENVIRONMENTAL REGULATION, TALLAHASSEE, FLA.; ROBERT MARTINI, TASK FORCE LEADER, DEPARTMENT OF NATURAL RESOURCES, RHINELANDER, WIS.; AND DR. ROBERT ARNOTT, ASSISTANT DIRECTOR, COLORADO DEPARTMENT OF HEALTH, DENVER, COLO.

Senator **Stafford.** Gentlemen, we appreciate your being here and for the committee, I apologize that events on the Senate floor and the interest in this subject of our members have overrun our projected time schedules.

I would ask you to reduce your oral presentation to 5 minutes, with the understanding that your full written statements that we have will be placed in the record.

I will go in the order in which you are listed.

Mr. Robert Flacke would you lead off.

Mr. **Flacke.** Mr. Chairman, thank you, very much for the opportunity of being with you today.

I am speaking on behalf of Gov. Hugh L. Carey, who is submitting a formal statement and testimony today, but I would like to very briefly review his thoughts, and New York State's thoughts in regards to acid precipitation and long-range transport of air pollutants.

We entered the area trying to determine what acid precipitation meant for New York State almost a decade ago. It was 3 years ago that we concluded that there was enough information within New York State's boundaries that actions had to be taken, and we commenced doing that in New York State. At the same time we began to build coalitions through the Governor's efforts with other States throughout this country, and at one point had a 26-State coalition which agreed in principle with the thought that action must be taken at this point in time.

We remain committed to this coalition. In fact, the number of States and Provinces have been increased. Just recently we have joined forces with the Province of Ontario and the Province of Quebec.

I would like to briefly review our thoughts.

If someone concludes something should be done, what can be done this year?

First of all, we have for a long period of time endorsed the fact there should be a national coal washing policy. We arrived at that position, oddly enough, from the efforts of Senator Randolph in his State and in many discussions with the American Electric Power Co. that coal washing per se brings great benefits to both the utilities and to the environment. We remain committed to that. And even the State of Ohio supports a coal washing program, which by the way we believe will increase, at the most, utility rates 6 percent.

We are hopeful, Mr. Chairman, that you and the other distinguished Senators can secure congressional approval of some type of comprehensive acid precipitation legislation this year.

In recognition of the continued insensitivity of the Federal Government for a long period of time—through different administrations—to the effects of acid precipitation, we have some simple and modest suggestions—other than coal washing—one recommendation is an emissions cap for sulfur dioxide.

Here in New York State, our average emissions of sulfur dioxide from coal-fired powerplants are equal to about 1.7 percent sulfur coal, whereas in many States, average emissions range from 2. to 3.3 sulfur.

The quantity of coal burned in those States using the higher sulfur fuels is anywhere from four to eight times that of New York State. Therefore, as a first step, we would suggest an emissions cap equal to the maximum sulfur content which we allow in New York State, for example, 2.5 pounds of sulfur per 1 million Btu's.

We believe that the Environmental Protection Agency should complete its studies of low NO_X burners for existing coal fired powerplants, and if such burners are feasible and can be done on an expedited basis, and preliminary information indicates they are, then they should be required at this point in time to help reduce the nitrogen dioxide emissions.

We have reviewed the bills that are before the Senate now and that your committee is considering. And we will give detailed comments on them.

Thank you.

Senator **Stafford**. Thank you, very much, sir.

The next witness would be Mr. Tierney, but I am going to withhold until Senator Mitchell can get here.

So the Chair intends now to skip over to Dr. John Holmes, to followed by Mr. William Hinkley, environmental administrator from Florida, unless Senator Mitchell gets back.

STATEMENT OF DR. JOHN R. HOLMES

Dr. **Holmes**. Thank you, Mr. Chairman.

I appreciate the opportunity to appear here before your committee today to present some recently acquired scientific data on the nature and extent of acid precipitation in California. Even though we have begun only recently to study the problem intensively, there is still a substantial amount of information available.

I don't propose to go through it all in my oral testinony. Instead, I will provide these documents to the staff so they can be entered into the record of this hearing.

Senator **Stafford**. I think that would be very helpful.

Dr. **Holmes**. I think you will find in reviewing this material that the acid rain problem in California is perhaps somewhat simpler but at the same time less well understood than it is in other parts of the country and in the world. But we are moving ahead to limit potential damage anyway.

We have faced such environmental dilemmas before. In fact, some of the testimony we have heard here today is reminiscent of arguments that went on in Los Angeles about photochemical smog.

The debate went on for years on all aspects of the problem. First, the polluters denied the existence of the problem. Next, they denied responsibility for the problem. Then they asserted that nothing could be done about it. Finally they argued that doing anything would be too expensive. They turned out to be wrong on all counts.

Now you have reached the point in the same sort of debate about needing to understand it better before you do anything.

I think the situation in Los Angeles was very similar in the technical realm as well. In fact, it is similar meteorologically, although on a smaller scale. We have a very concentrated group of pollution sources in the western part of the basin: dense population, heavy traffic, the coastal powerplants, the oil refineries, the harbor. But we have the worst smog problem in the eastern part of the basin, perhaps 100 miles to the East.

We know there is a general movement of air from the west to the east. And, when we started to clean up Los Angeles, we didn't understand all the details of this, but we just assumed all sources were equally guilty and we began to adopt control measures for both mobile and stationary sources, reasonable measures we thought could be implemented at reasonable costs.

Now, we have gone through a period of 10 years of very extensive research, establishing a lot of the details of atmospheric chemistry, tracing air movements, making extensive measurements throughout the basin, developing complicated models that can simulate smog formation.

And it is clear our original assessments 10 or 15 years ago were essentially correct—all sources in all the coastal areas contribute to the smog problem inland. Source-receptor relationships change from hour to hour, from day to day, from year to year, as a result of what turn out to be very subtle changes in meteorology. It is impossible, we found, to finetune a control strategy.

In other words, you cannot clean up one kind of source at one location and predict with any degree of certainty that you are going to get a benefit of a certain magnitude downwind at any particular location.

I think the acid deposition problem in the East is much the same, very much the same. I think that if it were studied with the same intensity over the next 10 years, you would discover pretty much the same thing we discovered in Los Angeles: that everybody is responsible to pretty much the same degree. The fluctuations in weather patterns are so variable that it makes little sense to talk about specific source-receptor relationships. It is a regional problem. It requires a regional regulatory framework if it is to be solved.

I think, further, that the time for the Eastern States to act is now, not 10 years from now after all the research has been done. If we had waited for all the research to be done before beginning to clean up Los Angeles, the city would be unliveable today. And I don't think the Nation can afford to allow the continuing acidification of lakes, streams, and forests of the Northeast while we scientists sort out the details of transport, chemical transformation and damage mechanisms.

Let me say just a few words about the situation in California. We know that the air and rain coming in off our Pacific coast is clean. The pH of that rainfall is well above five. So, as a result, we know that any acid precipitation we measure we make ourselves; it is not from some other nation or State.

We also know our atmosphere, particularly along the coast where there is a combination of fog and smog, have a unique ability to convert sulfur oxides and nitrogen oxides to sulfates and nitrates.

These compounds make up a very large part of our particulate burden. The Los Angeles brown haze is sulfates and nitrates, to a large extent. We have studied them for a long time. We learned, that later these sulfate and nitrate particles are very acidic. So in 1976 and 1977, we began to measure our precipitation in Los Angeles and the northern part of the State.

I don't mind telling you as a scientist I was astounded at what we found. The average pHs of rainfall range from 10 to 100 times above the baseline that we measure at the coast. On the worst days, during the worst storms, pH readings of 500 to 1,000 times more acidic than normal are found in Los Angeles and San Jose near San Francisco.

These are certainly comparable to the readings we have heard about here in the East and Northeast. These findings are summarized in some detail in the material that I am giving to the staff.

I think one of the facts we have discovered is so important I would like to mention it in my testimony.

You have heard that the acid of rain in the Eastern United States is attributed to sulfur and nitrogen oxides in the ratio of about 2 to 1.

In California, the situation is reversed. About two-thirds of the acidity is caused by nitrogen oxides and only one-third by sulfur oxides.

Most of these nitrogen oxides are emitted by cars. For this reason, as well as others that this committee has heard about earlier, we are very concerned, along with Senator Hart and Senator Baucus, about the drive to weaken the Federal auto emmission standards for nitrogen oxides.

Any substantial change in these standards is going to make it extremely difficult for California and the other Western States to deal with the acid rain problem.

In the area of effects, we really don't have much data yet. We are in the process of trying to gather it. The only data we have that shows long-term trends are for reservoirs in the Sierra Nevada.

For example, the Hetch-Hetchy reservoir in the Central Sierras, that supplies water for the city of San Francisco: Its acidity has doubled over the last 25 years. It has been increasing more rapidly in the past 5 or 10 years. This indicates to us the smaller lakes and streams at higher altitude that supply the reservoir are becoming acidic with alarming rapidity.

Where are these smaller lakes and streams? They are in Yosemite National Park, which we in California are proud of and I think the Nation is. It is the crown jewel of our national park system. And it is at the beginning stages of suffering damage from acid rain.

So, to conclude, I think we all agree, certainly as a scientist I agree, that we need to do more research and determine just how much acidity these aquatic ecosystems and soils in California can absorb without showing adverse effects. But while these studies are underway, we are at the same time implementing control measures for sulfur and nitrogen oxides that are going to limit acid deposition and, we hope, reverse the trend in this decade.

It seems to us in California that because this problem is so insidious, it is a problem that can develop slowly, almost unnoticed over years and decades and then, suddenly, manifest itself as the death of dozens or hundreds of lakes or the rapid drop in productivity of forest or fertile fields that action is call for it now, not later. We, in California, believe that the Congress is going to have to take the lead in requiring the States to do everything we can to avoid any further increase in the acidity of rain and snow falling on California and on the rest of the Nation.

I think we need to move as quickly as is practicable to reverse what appears to be a very disturbing trend, with the prospect of even more wide-spread irreversible damage to forests, agricultural lands, lakes and streams.

It seems to me that to do otherwise would be utterly irresponsible.

Thank you.

Senator STAFFORD. Thank you, very much, Dr. Holmes.

I did intend to note that I was particularly pleased with the sensitivity in New York to the problen, because my State is right downwind from you across Lake Champlain.

Mr. FLACKE. Actually, Senator, we are neighbors. I live in Lake George. As the crow flies from you, it is not very far.

Senator STAFFORD. I will revert to our original schedule and ask the attorney general from Maine, Mr. Tierney, if he will make his statement.

Senator MITCHELL. Mr. Chairman, could I take a moment to welcome the attorney general who has displayed remarkable vigor and initiative in his tenure as attorney general in Maine.

One of the problems to which he has addressed himself as best he could at the State level is the problem of acid rain. So we are very pround of his performance as attorney general and delighted to have him here today. I know the members of the committee join me in welcoming him.

Senator **Stafford**. Mr. Attorney General, having once served in that capacity in my State, I know somewhat what you are facing.

STATEMENT OF JAMES E. TIERNEY

Mr. **Tierney**. Thank you, very much, Senator Stafford and Senator Mitchell.

I speak this afternoon not only on my own behalf and Governor of the State, but also on behalf of the New England attorneys general and of New York and New Jersey, who join in supporting Senator Mitchell's legislation and other matters which I understand have been submitted to you in the record previously.

I will defer any scientific testimony that I am prepared to give. Suffice it to say, we strongly support the National Academy of Sciences report.

I would like to talk a little bit about policies. I don't have to remind this committee of the commendable efforts of Congress to fight air and water pollution. Indeed, due to the efforts of many people in this room, billions of dollars, public money, and private sector money, have been spent in fighting these problems.

Maine people have always treasured their environment. People, I am sure many people in this room, who have traveled to my State have enjoyed the clean lakes and streams and breathed the clean air. What you may not have seen is behind that beauty is a deep dedication of all of our citizens, individual and corporate, toward preserving and protecting that environment.

Life is not easy in Maine. We are remote from America's economic mainstream. Winters are long and summers are short. But a million of us decided Maine is where we want to raise our families and lead our professional lives.

Many times we have had to make significant financial sacrifices to preserve our environment. The present frustration of our citizens facing the acid rain problem is now growing to anger. Despite our years of work and sacrifice and being a leader in the environmental movement, we sit by feeling helpless, as the rain falls and fish die and the prime resources of forestry and agriculture are threatened with pollutants brought from other States.

In 1977, Congress recognized the dangers of interstate pollution and was determined to establish a mechanism to address the problem.

As Attorney General, and I know as a former attorney general you know of what we speak when we represent States, I can assure the attempts of running down every conceivable solution under the current Clean Air Act have been among the most frustrating of our collective efforts.

My recent petition under section 126 of the act filed over a month ago has yet to receive a simple acknowledgment from the EPA. Given the cutbacks alluded to by Senator Baucus and Senator Mitchell, I am not sure they have taken the time to read it.

Senator Mitchell has presented a bill to stop the problem, or keep it from getting worse, and reduce the precipitating emissions by 40 percent. I am sure my scientific background rivals each of the Senators on this committee. So I go back to a very simple fact my mother used to tell me, what goes up must come down.

If you can limit what goes up, it seems to me we are going to make some substantial progress.

I would like to say I am not insensitive, in closing, to the difficulties facing the industries in the midwestern part of the United States. I understand the tremendous competition they are under from foreign markets. I understand their facilities are outmoded.

Maine people have already done much. Maine people have already solved as many problems as we possibly can. We don't come to Washington easily to ask for help. We are self reliant, independent people. We lead the Nation in conservation of energy. We were the first State in this country to have wood as a prime source of heat.

Our paper manufacturing industry is changing procedures into integrated design to save energy and reduce pollution in a responsible fashion.

Senator **Chafee**. Mr. Chairman, I don't want to interrupt the distinguished Attorney General. We have a problem here, as I see it, in that I don't know how late people will be able to stay. But in all fairness, the opposition, or the people on the other side, some of whom are going to be on the next panel, if this is going to be our last day of hearings, we have got to leave some time.

I wonder if it would be possible for those on this panel to make their statements quite brief.

Senator **Stafford**. Well, the Chair has asked this panel to try to do it in 5 minutes so we can accommodate the last panel, understanding their full statements will be in the record. We won't charge you for that time.

Mr. **Tierney**. Thank you, Senator, I am down to my last sentence.

Senator **Stafford**. No one can say you haven't complied.

Mr. **Tierney**. I know a balance has to be struck. The point I am making is the people of my State have made their sacrifices and made them substantially, and that balance point cannot be at the balance point that it destroys our State's region and environment.

Thank you, very much.

Senator **Stafford**. Thank you, Attorney General Tierney.

Next, we will hear from Mr. William Hinkley, environmental administrator, Florida Department of Environmental Regulations.

STATEMENT OF WILLIAM HINKLEY

Mr. **Hinkley**. Thank you Mr. Chairman, members of the committee. We appreciate the opportunity to be here. I also have submitted a written statement, which I ask be included in the record.

Senator **Stafford**. Without objection.

Mr. **Hinkley**. Very briefly, we know we have an acid rain situation in Florida. I am reluctant to say it is a problem, but we do have acid rain. Average pH levels below 4.7 now occur over three-quarters of the State. Generally, Florida's acid rain is not as acidic as that reported in the Northeast, but because Florida has approximately 75 percent greater rainfall the full deposition of acid on the ground may be as much as a third or a half what is occurring in the Northeast.

We don't have very good pH data for rainfall, but we do know through inferential, analytical techniques that rainfall has gotten more acidic in Florida since the fifties, that deposition of acid has increased fourfold. Given that sources of sulphur from ocean and biogenic sources have remained constant it seems this is coming from manmade sources. We don't know where. The acid rain is presently about a million tons of sulfur dioxide is being emitted in Florida, about 70 percent from utility generating plants.

When we compare summer rainfall to winter rainfall, summer rainfall is slightly more acidic in winter. That is important because we have a dramatic change in meteorological conditions. In winter we have frontal activity coming principally from the north. If we were experiencing interstate transport of acid rain precursors, then we might expect the acidity of rainfall to be greater in the winter than summer. But it is the reverse. That leads us to think it is a homegrown one. It is our own utilities creating it, but that is pretty much speculation at this point.

We don't know to what extent Florida acid rain precursors are going the other way, to the north and west. Our best estimate is something like 5 to 10 percent of the SO_2 generated in Florida makes its way across the border, but we are not clear on that at all.

We don't know very much about the ecological effects of acid rain in Florida. There has been one fairly important study done on a series of lakes in north Florida. An area that was compared with an area in south Florida where rainfall is more normal. We have found the north Florida lakes have dropped about a half a pH in it since 1960, so there has been a decrease in pH. We can't find a reason for it. There also has been a change in aquatic ecosystems in the northern lakes, including decreases in chlorophyl A levels, changes in phytoplankton populations and a general reduction in both biomass and species richness. But we have not yet been able to find a decrease of sport fish.

We have tried to look at the soils in Florida to determine the buffering capability of soils. We have found those soils used generally for agriculture have a high-buffering capability and are also frequently limed.

On the other hand, we have a series of soil types in Florida that are the base for very environmentally unique areas in the State, and they have a low-buffering capability, low-cation exchange capability, so they are susceptible to acid rain. These are leached sand that don't have any buffer capability.

In terms of aquatic organisms, we have a unique situation in Florida in terms of natural acidity of many Florida waters. The Suwanee River and the Okeefenokee Swamp have pH values of 3.5 to 4.2, but those are natural pH values and there are some healthy sport fish in the swamp and upper reaches of the Suwanee. That is another key, that biota in Florida has apparently adapted to naturally acidic pH water.

To summarize, we know we have acid rain in Florida, but we don't know what it is doing to us. We have some evidence of ecological effects, but we can see no evidence of sterilization of lakes such as is occurring in the Northeast. On the other hand, we have a lot to lose. We tremendously rely on tourism. Our fresh waters are used tremendously by tourists. We have a tremendous agricultural investment. We know we have a lot to lose and I wish we knew more than we do.

In terms of the legislation, we support the positions of the NGA and the National Commission on Air Quality, and it seems to us those positions are incorporated in 1706 and 1719.

We do have a couple of concerns. I think our primary concern is the relationship between acid rain and coal conversion. We would hope the committee and Congress can clarify how these two national objectives are going to be integrated. Florida is tremendously reliant on imported oil, something like 47 percent of the State economy is oil dependent, versus 15 percent nationally. Florida Power & Light is the highest user of fuel oil in the country. We have got to reduce our reliance on foreign imported oil. We have something like 40 percent of the megawatt size that can be converted from oil to coal, and we need to know.

We are working now with our utilities on how these conversions are going to be implemented and we need to understand. It isn't so much we are opposing controls for acid rain, but the integration of controls for acid rain for coal conversions are important.

We are concerned about allowance for growth. Whether we like it or not Florida is growing. The population between 1947 and 1980 increased by 43 percent. Florida was the third fastest growing State in the country. By the year 2000, we are expecting the population to double again. We need new capacities whether we want it or not. We need to have coal-fired plants, all of which will meet new source standards. But our reading of 1706 seems to be there would be no allowance for new capacity even if it met new source standards without identifying some reduction elsewhere in the region.

S. 1709 does exempt new plants from new source standards.

Senator STAFFORD. Can you summarize now?

Mr. HINKLEY. Our basic position is that in those areas of the country where the problem is apparently severe, we think that action should be taken. In those areas of the country where we don't have as clear a picture, such as Florida, maybe we could move at a different rate. We have talked in our testimony about having differential criteria or breaking that acid control region into more than one area.

That is about it, thank you, Senator.

Senator STAFFORD. Thank you very much, Mr. Hinkley.

Next is Mr. Robert Martini from Wisconsin.

STATEMENT OF ROBERT MARTINI

Mr. MARTINI. Wisconsin is a State which has been studying acid rain since June 1979. We consider it a serious problem. We have not identified any direct danger such as the dead lakes they have found in New York, but we are convinced we will experience the same kind of damage in the foreseeable future if we don't reduce our acid deposition loading rate.

In Wisconsin we estimate our loading is 20 kilograms per hectare per year of sulfate which is about double the recommended limit that is listed in the United States/Canada assessment document on the aquatic impacts of acid deposition which we provided data for and commented on and is to be released in October. I have attached a copy of that report to my testimony and ask the report be included in the record.

We know there will be some danger to lakes in the State of Wisconsin. Our lakes are probably more susceptible than other areas of the United States. We are listed as one of the four most susceptible areas of the United States to acid deposition damage. This is also a State that has approximately a $5 billion per year tourism industry. We sell more nonresident fishing licenses then any State. We are concerned about the aquatic impact in addition to other terrestrial impacts.

We testified in September 1980 before this committee on the potential economic impacts on the State of Wisconsin, and we feel that they could be substantial. We do not know how much time we have left before these impacts may be felt, but we are convinced the loading rate we have now is sufficient to allow these damages to manifest themselves.

We also believe that acid deposition is only a recent phenomenon in Wisconsin, which probably sets us apart from the Northeast. Data in the literature indicate as recent as the early seventies, late sixties, our rainfall was approximately normal. Now it is 10 to 100 times more acidic.

Senator **Chafee**. I didn't quite understand that. You said you thought your rainfall was normal and what changed?

Mr. **Martini**. The rainfall in the State of Wisconsin in published reports from the sixties and early seventies was approximately normal, in the five range. Right now, in 1980, 1981, our rainfall is being measured quite frequently at the 10 to 50 times as acid as normal level, an approximate pH of 4.4 to 3.7.

Senator **Moynihan**. That is a change.

Senator **Chafee**. That is a very dramatic change.

Mr. **Martini**. Part of this change may not be real. Part of it may be the problem of measuring historical rainfall.

Senator **Chafee**. In other words, your prior figure may not be accurate?

Mr. **Martini**. That is true. Although these trends have been published, the data is very limited for the early period. We do think we have experienced an increase, although it is very difficult to quantify the magnitude of the increase.

Because of this potential problem in Wisconsin, we have instituted a fairly rigorous series of State and federally funded studies that are intended to determine exactly what the impacts are. These studies have been going on for 2 years now. Of course, as many of the other studies have found, they have raised more questions than answers. We feel study and research needs to be conducted but the ultimate goal needs to be a reduction in total pollutants throughout the eastern part of the United States. We are encouraged by the tone and intent of the bills that have been introduced to control acid deposition.

Our Natural Resources Board, policy board, has gone on record in the past and has submitted to Congress and EPA a position that advocates additional research but also advocates steps taken very soon to reduce the level of emissions and levels of pollutants that are presently being emitted.

As far as comments to the specific bills, we have only had a couple of days to review and we would like to provide you with more detailed comments later. But we do substantially agree with the findings of fact that precede the bills. We think there is substantial agreement that sulfur dioxide and nitrogen oxides do cause acid deposition and this deposition is causing damage in the country.

We favor the approach in the Dodd bill because it appears to give States who will ultimately implement those policies the maximum flexibility in identifying the problems in their particular State. This bill enables States to get reductions in interstate transport of a number of pollutants, not only those pollutants that cause acid deposition.

We agree with the Moynihan and Mitchell bills, there needs to be a reduction of approximately 50 percent in current sulfur dioxide loads. Again we base this on the United States-Canada transboundary air pollution aquatic impacts document which comes to approximately that same conclusion; 50- to 70-percent reduction is needed. We feel this needs to be done in the near future.

We also are encouraged by a provision in the Dodd bill that requires the Administrator of EPA to act promptly because we don't think the Environmental Protection Agency has acted promptly in interstate transport disputes in the past. We feel this is very necessary.

We are also concerned about the apparent lack of strong enforcement posture taken by EPA and the apparent weakening of the enforcement arm of EPA. We wonder how the provisions of these three bills can be carried out with substantial weakening of an effort on the part of the EPA which we already consider to be inadequate.

We think the Environmental Protection Agency must increase the amount of effort put into the problem instead of decreasing it.

Although we concur with the goal of reducing sulfur dioxide and nitrogen oxides, we feel the States should have maximum flexibility in implementing reductions. We welcome innovative techniques for reducing overall loads.

That summarizes my testimony, and I have submitted a fairly lengthy document to be included in the record.

Senator STAFFORD. Thank you, Mr. Martini, your full document will be made a part of the hearing record.

Now, we will come to the last witness, Mr. Robert Arnott, assistant director, Colorado Department of Health.

Mr. ARNOTT. I will be very brief. I too have a statement for the record.

Senator STAFFORD. Without objection, it will be included.

STATEMENT OF ROBERT A. ARNOTT

Mr. ARNOTT. What you have heard today is that acid rain is principally a problem of the Eastern States. I think with respect to Colorado we have some concerns it might be a national phenomena that also impacts the Western States, particularly the higher elevations where we have our most sensitive ecosystems. We have other concerns in Colorado as well because we are facing major industrial growth in energy, with special emphasis on oil shale.

We know this will undoubtedly increase the emission of acid rain precursors. Also, the accompanying population will increase the emissions from mobile sources as well through the State.

Because of this concern, the Governor's Scientific Advisory Council assigned a technical subcommittee to study this problem, and it made several findings. The most important was that the high-altitude lake and stream areas of the State are, in fact, the areas which are most susceptible to acidification, and these areas also receive a disproportionate amount of our total precipitation. This further adds concern.

I would simply add in summarizing my testimony four recommendations. I unfortunately made these four recommendations before I had access to the bills but believe the overlap is significant.

The level of research must be significantly expanded Reasonable and practicable measures should be implemented immediately to reduce emissions of sulfur and nitrogen oxides from existing stationary sources and to define regional or State specific emission goals. I would point out this recommendation is in concert with the policy position adopted by the State and territorial air pollution program administrator in June of this year as one of their recommendations on changes in the Clean Air Act.

The third recommendation would be that specific statutory language should be enacted to allow broader authority to control long-range and regional air pollution sources. This would include at least modifications to sections 110(a) and 126 of the present act. Both of those are addressed in the bills proposed.

Finally, no relaxation of the mobile source emission rate for oxides of nitrogen should be enacted due to evidence which indicates that nitric acid deposition is a significant contributor to overall acid deposition, particularly in the Western States.

That very quickly summarizes my written statement.

Senator **Chafee** [presiding]. Thank you very much, Mr. Arnott. I want to thank everybody on the panel for their contribution here.

Why don't we go to the next panel.

Senator **Moynihan**. Mr. Chairman, would you allow me just to say this. Because of the voting I missed the testimony of Mr. Flacke, of New York, and I want you to know I read the statement and appreciate it. I would like to say if you want to see this happening you ought to get in one of his helicopters and fly over one. The interesting thing about a dead lake is it is beautiful aquamarine because there is nothing alive.

I have something to say about Wisconsin. I have been with the commissioner in which, in a 24-hour period, we have measured the acidity of a remote lake in the Adirondacks and we had about a 5.2, and then a day of rain we come back and it is 4.2. It is an appalling experience and it obviously has consequences. We do know a lot more about it than apparently some people think.

Thank you.

Senator **Chafee**. Thank you, I would like to say to Mr. Arnott. It seems to me in your first recommendation,

> The level of research must be significantly expanded to include additional measurement of actual impacts, interstate and international transport from sources, relationships between acid deposition and visibility, increased knowledge of materi-

als damage and welfare impacts and a determination of the chemistry and rate of specific precursors, principally oxides of sulfur and oxides of nitrogen.

Aren't we going to be in a problem there, because the utility people say, to take these practical measures is extremely expensive and to provide we require these very expensive measures before you have completed your research is an unfair imposition on us and our customers?

What do you say to that?

Mr. ARNOTT. I guess my posture would be there is sufficient research to indicate a problem, and that the kind of remedies which are readily available are fairly cost effective such as national coal washing. I would also indicate in the bills before you, there is an approximate 10-year implementation timeframe outlined for these controls to become effective.

It seems to me if we are serious about this major research effort, the answers will become available before that timeframe elapses. We can make midcourse corrections if necessary.

Senator CHAFEE. I am not disputing that. I am just saying midcourse corrections to somebody who is making an extremely expensive installation is often not practical.

Mr. ARNOTT. Right. I guess I am not seeing the major costs being in the first 2 or 3 years of this bill.

Senator CHAFEE. OK.

Senator MOYNIHAN. Mr. Chairman, would you allow me one statement on that because I wasn't able to talk to Mrs. Bennett either.

There was a time when the EPA seemed to think that it knew more than it did. Now we are getting in a situation where it claims to know nothing, and neither is warranted. Mrs. Bennett gave us a model of science which no scientist I think would agree to. She would say that any regulatory action at this time would involve guessing. Now I am not a scientist, but I have lived among them, as a matter of fact served on the President's Science Advisory Council. And I would tell Mr. Tierney what goes up doesn't necessarily come down. It is called CO_2, and it is producing a well-known effect.

Maybe the particles are canceling it out, we don't know. But any judgment in science involves guessing. It is called measuring probabilities, and the probability here is they get better and better all the time. But the probabilities are already pretty high. And you will always act on incomplete knowledge, and if you wait for complete knowledge you never act at all. That is obviously a truism but it is nonetheless one we have to live with in Government.

Senator CHAFEE. Thank you, Senator; thank you, gentlemen.

Now let us have the last panel. Mr. Gerstner, Mr. Farrand, Mr. Hawkins, and Dr. Hair. I have to leave now, Senator Stafford will be right back, and I am going over to vote. We will just recess until Senator Stafford returns.

[A brief recess was taken.]

Senator STAFFORD [presiding.] The committee will please come to order.

We will ask our guests to refrain from conversation and be as quiet as possible, please.

On behalf of the committee, I understand the last panel has been invited to the witness table, and I would like to extend my gratitude to all of you for being here and our apologies, the time frames for today sort of got out from under us. It happens quite often here on the Hill. But we do try to run this committee on time and we had hoped to finish by 1 o'clock. If we are keeping you late, I apologize.

If I mispronounce the name, please accept my apologies.

The first member listed on the panel is Mr. William Gerstner, who is executive vice president of Illinois Power Co., Decatur, Ill.

Gentlemen, we will place your full statements in the record. We would ask you to summarize them as briefly as you can.

STATEMENTS OF WILLIAM C. GERSTNER, EXECUTIVE VICE PRESIDENT, ILLINOIS POWER CO., DECATUR, ILL.; CHRIS FARRAND, VICE PRESIDENT, PEABODY COAL CO., WASHINGTON, D.C.; DAVID HAWKINS, STAFF ATTORNEY, NATURAL RESOURCES DEFENSE COUNCIL, WASHINGTON, D.C.; AND JAY D. HAIR, EXECUTIVE VICE PRESIDENT, NATIONAL WILDLIFE FEDERATION, WASHINGTON, D.C.

Mr. **GERSTNER**. My name is William C. Gerstner. I am executive vice president of Illinois Power Co. and chairman of the Utility Air Regulatory.

I ask my full statement be placed in the record.

Senator **STAFFORD**. Without objection, it will be.

Mr. **GERSTNER**. I am speaking today on behalf of the Edison Electric Institute, the trade association of the electric utility industry.

Pursuant to the chairman's request, I have pretty well chopped up my oral statement.

Senator **STAFFORD**. Might I inquire if you were present yesterday when the chairman was the speaker at a luncheon at the Edison Electric Institute?

Mr. **GERSTNER**. No, sir, I was not, but I have received comments on it.

Senator **STAFFORD**. You probably missed the best speech I have ever made.

Senator **MITCHELL**. That is still to come, Mr. Chairman.

Mr. **GERSTNER**. I would like to thank the members of the committee for giving me the opportunity to testify today. While my prepared statement addresses all three bills, I will limit my oral remarks to the two bills introduced by Senators Mitchell and Moynihan.

Before turning to the specifics of the bills, I would like to make it clear that we believe the emission reduction programs contained in S. 1706 and S. 1709 are unwarranted and that we oppose these bills.

In sponsoring the legislation that led to the passage of the Acid Precipitation Act, Senator Moynihan himself underscored Congress' concern that premature action could prove disastrous.

The Senate is proposing to learn something about the subject before it mandates solutions. It will be possible to make profoundly gross mistakes here if we do not do some research first, mistakes that would cost billions.

We believe that there has been no new evidence since this statement was made which justifies rejecting the reasoned approach established by Congress last year.

The most serious uncertainty associated with various emission reduction proposals is the enormous doubt as to whether such reductions would significantly alter the pH of rainfall at significant distances downwind.

The point is that at present we have no firm evidence that emission reductions will make rainfall less acidic or that they will have any significant effect on the process of aquatic acidification.

Even if there was sound evidence for concluding that emissions reductions would significantly reduce ecosystem acidification, a thorough evaluation of whether resulting environmental benefits outweighed the costs of those reductions would be necessary before any rational control decision could be made.

Let me turn specifically to our concern with Senator Mitchell's bill which would impose an immediate moratorium on any increases of sulfur dioxide (SO_2) and nitrogen oxide (NO_x) emissions in a 31-State region, and requite a 10 million ton reduction in SO_2 emissions in that region within 10 years after enactment.

Preliminary results of an analysis of S. 1706 being done for EEI indicate that in 1979, stationary sources in the 31-State region specified by the bill emitted approximately 23 million tons of sulfur dioxide. Thus the bill would require that emissions from sources in this region be reducted by 44 percent, exclusive of emissions reductions which would be required to offset emission increases between January 1981 and the date of enactment and offsets necessary to allow new source construction, modifications, coal conversions and SIP revisions generally. Table 1 in my prepared statement demonstrates the magnitude of these emissions reductions on a State-by-State basis.

In view of the extraordinary magnitude of the emission reduction requirement imposed by S. 1706, compelling justifications should exist to support its imposition. Yet when asked recently the basis for the 10 million ton figure, at hearings before the Health and Environment Subcommittee of the House Energy and Commerce Committee, Senator Mitchell candidly acknowledged that it was "arbitrarily" chosen.

The institution of a 10 million ton SO_2 reduction requirement would require source owners to examine a broad variety of control measures in an effort to minimize emission reduction costs. Although in certain circumstances sources may elect to shift fuels, compliance with an emissions rollback of this size would clearly necessitate considerable capital expenditures. Major sulfur dioxide emitters could, for example, be forced to meet reduction requirements through the installation of flue gas cleaning devices, such as scrubbers or soda ash injection systems. Such controls are enormously expensive, particularly when retrofitted at existing facilities. There is little doubt that widespread scrubbing would be required to meet the emission reductions mandated by the bill. Recent estimates indicate that the capital costs alone of scrubber retrofit would be staggering. The Department of Energy, for example, has estimated that the capital costs of retrofitting the 50 largest SO_2 emitters east of the Mississippi would exceed $12 billion.

DOE's estimates are consistent with figures cited by the Environmental Law Institute of $14.8 billion, and the General Accounting Office of $7 to $18 billion, and these estimates are undoubtedly conservative.

Proponents of emission reduction requirements often suggest that consumers would only be subjected to minimal increases in electric rates with the enactment of a major SO_2 reduction program. These advocates, however, often fail to indicate that the modest increases they cite—2 percent—are arrived at by diluting the costs over large geographic regions, when in fact the bulk of the cost would be borne by relatively few ratepayers. At the House acid rain Hearings held on October 20, for example, Ohio EPA Director Wayne Nichols testified that emission reduction requirements on a scale envisioned by S. 1706 could lead to rate increases of 15 to 20 percent in parts of 0hio—in sharp contrast to the "reasonable" 2 percent increase suggested by many in the environmental community.

We support the concept of substituting NO_x reductions for SO_2 reductions embraced by section 185(b) of S. 1706. Although we disagree with the premise that additionl emission controls should be imposed, we believe that if any legislation calling for emissions reductions is enacted, decreases in SO_2 and NO_x should be treated interchangeably.

We do not subscribe to the view that the NO_x/SO_2 reduction ratio must exceed 1.

Senator Moynihan's bill also mandates massive $S0_2$ emission reductions from major stationary sources in the same 31-State region but approaches this end in a somewhat different fashion than S. 1706. The Moynihan bill contains no immediate moritorium on SO_2 and NO_x emissions and rather than the 10 million tons reduction within 10 years required by the Mitchell bill, it would require approximately an 8,200,000-ton reduction in SO_2 emissions by the end of 1991.

Many of the comments on S. 1706 in the previous section of my statement are equally applicable to the Moynihan bill. Rather than repeating them here, I will simply comment on those features of S. 1709 which we believe merit additional comment.

According to our preliminary calculations, ther are 15 States which would not be required to achieve any reduction in emissions under S. 1709. As shown on table 2, the formula contained in S. 1709 for calculating the required emission reductions insures that its major impact will be borne by the remaining 16 States.

In some cases the emission reductions required of States under the Moynihan bill would be greater than those required by Senator Mitchell's bill, in others they would be less.

For example, under S. 1709, the reductions required for Illinois would be approximately 612,000 tons while under S. 1706, Illinois' requirement would be approximately 884,000 tons. Interestingly, under Senator Moynihan's bill New York would be required to reduce its SO_2 emissions by approximately 50,000 tons, while under the Mitchell bill its requirement would be approximately 302,000 tons.

While we have not yet completed our analysis of the economic impacts of S. 1709, I think it fair to say that those impacts in the States affected will be similar to the costs I noted above in reference to S. 1706. Those economic impacts will be severe.

S. 1709 does not impose an immediate moratorium on SO_2 and NO_x emissions. From this standpoint, therefore, we believe it preferable to Senator Mitchell's bill.

In closing, Mr. Chairman, let me emphasize two points:

First, we do not believe the emissions reduction program required by these bills are warranted because there is no firm evidence that they will have any beneficial effect. When we are talking about spending between $10 and $30 billion, I think the public will demand some assurance that those expenditures will result in significant environmental benefits.

Second, the Federal Government now has in place the acid rain assessment program established by last year's Acid Precipiation Act. We believe that the schedule for obtaining the result from that program can and should be accelerated from 10 to 5 years.

When those research results are available, they should answer many current questions.

At that point, Congress will have the facts on which to decide whether emissions reductions or other control programs are necessary.

Thank you.

Senator STAFFORD. Thank you very much, Mr. Gerstner.

Next is Mr. Chris Farrand, vice president of the Peabody Coal Co.

STATEMENT OF CHRIS FARRAND

Mr. FARRAND. Thank you, Mr. Chairman, I will abbreviate my remarks considerably.

Peabody has prepared an analysis of the economic impacts of S. 1706 on a State-by-State basis, as well as for the entire 31-State area affected by the bill.

We have reviewed these numbers with staff previously, but I just want to go over a few of them.

Our analysis shows that under the assumption that the least-cost method of attaining reductions in SO_2 emissions of this magnitude, would be fuel switching, rather than the application of flue gas desulfurization equipment. Under that assumption, 307 million tons of coal currently burned by the utilities in this region would be displaced, and the result of that displacement is an increased consumer cost amounting to $3.2 billion annually for the fuel cost differential alone, and the displacement of some 188,000 jobs in the mining sector.

We believe these estimates are conservative, and we have discussed our methods of analysis with the staff previously. They do not account for any inflation. They do not account for any extra inflation, meaning the inflation effects of very sharp increases in demand for certain types of coal or for certain methods of transportation. For example, we estimate that if the cost of the low-sulfur or acceptable coal that would have to be used to displace the current coal would rise by $10 a ton, the combined effect would not be $3.2 billion per year, but a figure close to double that. So we believe we have been most conservative.

We have not applied a tonnage penalty if the coal were subbituminous and you had to find added Btu's to meet energy requirements. We have not applied capital cost for boiler modification or other equipment that might have to be modified. Of course, our analysis is based on precise blending of coal with no margin of safety for coal variability.

One empirical example, our figures show the cost of this fuel switch in Missouri would be about $261 million. One utility in that State has told us their estimate for their powerplants alone is in excess of $200 million. So we believe that we have not been overly generous in our figures.

Just to run down a few of the States that would be affected: Indiana consumers would probably be an extra $450 million a year. Alabama, which strangely enough is known to produce relatively low sulfur, would pay $289 million a year extra; Georgia, $215 million; Illinois, $232 million; Kentucky, $234 million; Ohio, $254 million; and Pennsylvania, believe it or not, $352 million.

Senator Randolph, your own State, we estimate, would have a fuel cost differential total of about $170 million per year.

We believe that these dislocations are considerable, particularly the job dislocations.

Obviously there would be increases in employment in areas of the country that produce low-sulfur coal. There are very few instances where the two types of coal are colocated. As a result, you would see very dramatic shifts in mine and mine-related employment.

I might add the figure we developed for employment impact uses not only the direct mining jobs, the miners themselves, but a multiplier applied to that for secondary effect.

Our multiplier is 1.5.

People tell us in the rural parts of the country where most of our mines are located, that is a very low figure and it is generally in the range of 2 to 3, rather than 1.5.

To reiterate some of the job loss figures that are also in my testimony, we estimate in Illinois the job loss effect would be in the neighborhood of 30,000 jobs; in Pennsylvania, about 37,000 jobs; in Ohio about 19,000; in western Kentucky, about 22,000.

There is a considerable effect in northern West Virginia, about 41,000, but we believe those will be substantially offset, if not totally, by employment in low-sulfur mining in the southern part of the State, and we just don't have that figure.

All in all, we find that this statute would have a very, very serious economic effect. We did not compute income losses. We did not compute the effect on State and local taxes or higher budgets to pay unemployment compensation benefits, and so forth. I might point out the displaced coal, the 307 million tons I talked about, has a current value exceeding $9 billion. So it is a severe economic effect this bill has.

The sort of frightful dislocation we find as a result of this bill is distressing to us in one sense, because we feel that there is no concrete assurance that SO_2 reductions, even reductions in this magnitude, will achieve the desired result in terms of acid rain reduction.

To that effect, I would like to submit for the record, Mr. Chairman, two statements that were prepared by Dr. Volker Mohnen of the Atmospheric Sciences Research Center in Albany.

Senator **Stafford**. Without objection we will place them in the record. (See pp. 568 and 599.)

Mr. **Farrand**. Mr. Chairman, Dr. Mohnen testified before the House Science and Technology Committee about a month ago, and earlier this year he submitted a statement before an EPA administrative proceeding in which he detailed the results of his study, as well as some other studies. And I am not a scientist, and I am not prepared to defend his work in essence. But the bottom line is that he can find no direct linear relationship between emissions of precursor gases like SO_2 and acid deposition. Or, put another way, the extent of acid rain, or acid deposition is not significantly determined by the amount of SO_2 put in the atmosphere.

Someone described it to me this way: There is a sizable reservoir of SO_2 at any given time in the atmosphere. The amount that gets converted to sulfates is a relatively small amount. The end result is you may put a big dent in what is in that reservoir and put no dent in what happens when it gets converted to sulfates and other forms of acid.

We feel, first, the bill is pointed at only one sector of the economy, meaning the utility and coal sectors, and saying, we don't know any other solution to impose so we are going to impose it on you. Second, we feel the way S. 1706 is drafted, the costs will be borne by a relatively small number of people. It happens that people who are most concerned about acid rain—and I share your concern, I am a trout fisherman, and I enjoy those lakes, I believe there is a problem—but the people who are most concerned about that are not the people who are going to pay. It is going to be people in other parts of the country.

Finally, I think we feel there is in place, if you accept for the moment that the existence of SO_2 in quantities is a serious problem, and that SO_2 reductions will have the effect of reducing acid rain, then Congress has already addressed that problem. Congress has in the new source performance standards of the Clean Air Act imposed strict limitations, the effect of which will be to reduce SO_2 loadings over time by about 50 percent. And what we are dealing with is a factor of time. That provision is already in place, and we believe it will achieve the same result.

Moreover, it will achieve the same result in a timeframe that allows you to be more certain that this kind of reduction will have the desired effect.

Mr. Chairman, that concludes my statement. I would be happy to answer any questions.

Senator **Stafford**. Thank you very much, Mr. Farrand.

The next witness will be Mr. David Hawkins, who is staff attorney, Natural Resources Defense Council.

Senator **Randolph**. Mr. Chairman, I was necessarily absent. I will have some questions and discussions with Mr. Farrand. If you would rather wait——

Senator **STAFFORD**. If it is agreeable, I would rather let the panel finish.

STATEMENT OF DAVID G. HAWKINS

Mr. **HAWKINS**. Thank you, Mr. Chairman and members of the committee.

My prepared testimony addresses three questions regarding the National Clean Air Coalition's position on acid rain control. They are: Why 10 million tons of reduction? Why focus on electric utilities? And why a Federal program? In the interest of time, I would like to address myself only to the first question.

We selected a 10-million-ton reduction target after asking ourselves two questions about alternative targets. The first was: How does the target compare to the ultimate emission reduction that we are likely to want in order to protect against natural resource damages? And the second question was: How much does the reduction target cost? Precise estimates of the ultimate level of control we are going to need are not available now and won't be available for many years, which is precisely why we need a program to act now and take a reasonable first step.

Recent studies, and especially the National Academy of Sciences study, estimated a 50-percent reduction in deposited hydrogen ions, which is the acid part of the emissions, would be appropriate to protect sensitive areas.

Comparing our 10-million-ton reduction proposal to today's emissions, it amounts to about a 43-percent reduction in eastern sulfur dioxide emissions, and that is ignoring completely nitrogen oxide emissions. Depending on the weight given to nitrogen oxide emissions, this 10-million-ton proposal amounts to a 34- to 38-percent reduction in the combined total of eastern sulfur and nitrogen emissions.

We believe this program of a 10-million-ton reduction is less than what we will ultimately need, but it is a good first step in reducing that damage.

Lesser reductions will do too little to reduce damage that is already occurring and will allow more damages to accumulate.

The second question we asked was, what will these programs cost? Here we had before us some studies done by the ICF consulting firm for the Department of Energy and the Environmental Protection Agency. We asked them to follow up on those studies and to do an analysis of what it would cost to reduce emissions by 10 million tons.

We asked them to use all of the same assumptions they used in the DOE and EPA study so the results could be compared. While we have not received a final report from ICF, they have provided us with partial results of their analysis.

The ICF analysis projects a 10-million-ton reduction established by 1990 would result in a 1.9-percentage increase in average eastern electricity rates, and an annual cost of the program of $2.4 billion. In the year 2000, the average rate increase would be 1.7 percent, and annualized costs would be $3.4 billion.

My testimony points out individual States will have rate increases both higher and lower than the average. But the highest rate increase will be around 7 to 8 percent, not the 15- to 20-percent amount stated by the utilities in their testimony.

Moreover, the States with the largest rate increase are among today's largest emitters. In 1990, after these rate increases are factored in, these States will still enjoy electricity rates less than those in the Mid-Atlantic and New England States which are suffering the damages.

Based on this analysis, the coalition believes a 10-million-ton reduction program can be accomplished at a moderate cost.

In short, we advocate a 10-million-ton reduction program because we believe it is a minimum first step necessary to reduce damage to our natural environment, and we can afford the cost of that step.

The Peabody Coal testimony raises the issue of coal job losses, and I would like to address that briefly in order to correct the record.

Peabody says 98,000 jobs could be lost due to coal shifting. There is only one way you can reach that conclusion and that is by ignoring three things. First, the Mitchell and Moynihan bills require control by 1990, and between now and 1990 there will be large increases in coal production.

The second is the Peabody analysis assumes all compliance will be by coal shifts. But the ICF study, who also did a study for Peabody, points out many will comply by coal cleaning and scrubbing. The study says there will be a 50-percent increase in use of the scrubbers in 1990 under this program.

Third, there will be large gains in eastern low and medium sulfur coal. These gains will largely offset production in high coal.

I apologize for throwing numbers at you, and I will supply them for the record, but I think it is important to correct the record.

For example, the Peabody analysis indicates a 45-million-ton loss in the State of Illinois. The analysis, after taking into account growth by 1990, other coal production increases, and the fact not every one will shift indicates a loss in Illinois, but not 45 million. Rather it projects a loss of 13 million. This is not a permanent loss, the analysis shows by the year 2000, Illinois will be producing 84 million tons more than it is today.

In Indiana, the Peabody study says a 24-million-ton loss. The analysis we have indicates a 3-million-ton gain.

In west Kentucky, rather than a 34-million-ton loss, our analysis indicates a 3-million-ton gain in coal production, and in east Kentucky, a 2-million-ton gain.

I know one Member is anxious about West Virginia, and in West Virginia, rather than a 31-million-ton loss, our analysis shows a net change from today's production of an increase of coal of 114 million tons.

The analysis shows similar results of plus 5 million for Tennessee, plus 9 million for Virginia, losses of 8 million and 9 million in Ohio and Pennsylvania respectively, but increases in those States by the year 2000 of 15 million tons and 27 million tons.

So this committee's work is going to be hard enough without getting both sides of the question. There will be some losses in high-sulfur coal production, but by the year 1990, this country nationally will be producing 1,244 million tons, that is 1.2 billion tons. That is a 50-percent increase over today's coal production of 778 million tons.

With this program, production will be 2 million tons less out of a 1.2-billion-ton figure.

Finally, if I might, Mr. Chairman, just a brief point on the question that Mr. Farrand also raised about the relationship between emission reduction and reduction in acid rain and the reference to Volker Mohnen's testimony.

The point that is being missed here is acid rain is one symptom of a broader problem of acid deposition. The sulfur that goes into the air comes down in two forms. It either comes down in rain or dry forms. What doesn't come down in rain comes down in dry form, and the next time it rains, the stuff on the ground dry becomes acid. Any sulfur that goes into the air, eventually does come down in one form or another.

Mr. Farrand is right, there is a large reservoir of sulfur in the air, and I wonder how the reservoir got that large. The point is, by reducing the reservoir, we are in less danger of being in over our heads.

Senator STAFFORD. Thank you very much, Mr. Hawkins.

The next member of the panel is Dr. Jay Hair, executive vice president of the National Wildlife Federation.

STATEMENT OF DR. JAY D. HAIR

Dr. HAIR. Thank you, Senator Stafford.

The National Wildlife Federation commends you for holding this hearing. The acid rain and long-range transport bills before this committee reflect several factors which are detailed in my written statement.

Let me just summarize what the highlights of that statement are.

One is, of course, the prestigious National Academy of Sciences' report issued in early September. It highlights the extreme seriousness of the acid rain problem in uncharacteristically firm terms. Among other conclusions, the report finds sulfur and nitrogen compounds from manmade sources to be the only plausible explanation for acid deposition, and that, the evidence for the role of powerplant emissions in the production of acid rain is overwhelming.

The National Academy of Sciences report should, but probably won't, lay to rest any reasonable doubts as to the need for expeditious action to control acid rain, and for action, in particular, to control powerplant emissions of sulfur dioxide.

In a similar vein, my staff recently surveyed acid rain scientists in selected States around the Nation. They found an almost universal endorsement by knowledgeable experts of the view that what is already known about acid rain justifies and requires immediate legislative steps to begin abating emissions of human-generated acid rain precursors.

Contrary to the contentions of those who think ignoring the acid rain problem or simply doing more studies will make the problem go away, acid rain is prevalent today and is growing worse.

My staff has compiled a series of maps showing the distribution of low pH rainfall and acid-sensitive soils and lakes in the 27 States east of the Mississippi.

Two of these maps, which superimposed maps of sensitive soils and surface waters on a map of U.S. congressional districts, are attached to my statement as exhibits 2 and 3.

My staff has also prepared a tabular representation of the acid rain sensitivities of the 27 eastern States in relation to both environmental impacts and materials damages.

Finally, there appears to be mounting evidence of acid rain impacts and vulnerability in a number of States west of the Mississippi River. In addition to our own statement, I would like to introduce into the record a report of the environmental defense fund entitled "Acid Rain Research in the Intermountain West."

Also, the International Association of Fish and Wildlife Agencies, the governing body of State and provincial agencies in the United States, Canada, and Mexico have asked to enter into the record a resolution they passed at their recent meeting.

Senator STAFFORD. Without objection that will be made part of the record. (See p. 785.)

Dr. HAIR. One other point. The International Union for the Conservation of Nature probably the most prestigious body worldwide concerned with scientifically based natural resources conservation, has a similar statement they would like to enter into the record.

Senator STAFFORD. Without objection, that will be made a part of the record, also. (See p. 736.)

Dr. HAIR. We regard acid rain as one of the leading environmental problems of this decade. So we are pleased to see these Senate bills which share a common recognition that the time for control is now. In particular, the National Wildlife Federation and the National Clean Air Coalition wish to convey our enthusiastic support for the complementary approaches of the Mitchell-Stafford (S. 1706) and Dodd-Durenberger (S. 1718) bills.

The Moynihan bill, although also a control-oriented bill, is less satisfactory than is S. 1706 in that it would accomplish a lesser degree of sulfur dioxide emission reduction, and does not give added emphasis in setting specific reduction requirements where States do not adopt adequate plans.

The Mitchell-Stafford bill represents a reasonable approach to reducing acid rain in the Eastern 31 States. We support the need for a 10-million ton reduction in SO_2 emissions over the next decade. The National Commission on Air Quality found a 7-million-ton reduction could be achieved at an increase in average utility rates of less than 2 percent.

Through the use of interstate trading or bubbling an additional 3-million-ton reduction in SO_2 could be achieved without significant additional cost. The 10-million-ton goal is extremely reasonable and represents only a third of the total SO_2 emissions in the United States.

Although we would have preferred a stronger Federal role, we are pleased that the Mitchell-Stafford bill does contain a backup system of Federal controls that becomes be immediately applicable if a State has not adopted appropriate control measures within 2 years.

In addition to the SO_2 emission reduction program set out in the Mitchell-Stafford bill, the overall program for mitigating acid rain should include the following:

First, protection of section 125 providing the authority to include use of locally derived coal to prevent serious economic dislocations; second, limitations on utility stack heights; third, control of nitrogen oxide emissions from mobile sources; and fourth, enhanced authority for States to protect the quality of their air from interstate pollution.

The latter is the focus of the Dodd-Durenberger bill, and we support that also.

In conclusion, we believe that further research will only confirm what is already known and well documented, and that is, acid rain costs our Nation billions of dollars each year and causes irreparable harm to the environment.

The causes of acid rain are known. The costs are real and profound. The trends are ominous and, as the Mitchell, Stafford-Moynihan and Dodd-Durenberger bills indicate, the time for legislative action is now.

Thank you, Senator.

Senator STAFFORD. Thank you, very much, Mr. Hair.

I think the Chair will reserve until last on one or two questions, and I would remind my colleagues on the panels that we have reserved the right to ask questions in writing.

I hope that is agreeable to you since some of the Members who would have liked to be here are now on the floor.

I will turn first to Senator Randolph, who I know has considerable interest in this discussion.

Senator RANDOLPH. Thank you, Mr. Chairman.

Mr. Farrand, you and Mr. Hawkins are in disagreement; is that correct?

Mr. FARRAND. It would appear that way.

Senator RANDOLPH. Well, what do you rely on, Mr. Farrand, to refute what Mr. Hawkins has said?

Since he followed you, I come to you first.

Mr. FARRAND. I think there is a basic misunderstanding about the way we went about our analysis. I said we used one basic assumption, and that is the assumption that coal switching would be the response of the utility sector. That is an assumption we used for purposes of our analysis that is not necessarily what will occur in reality.

Given the magnitude of the coal switching that would occur as a result of the reduction, undoubtedly many utilities would have to go to a technological response, meaning scrubbers.

Our analysis didn't get into that. We assumed that would be a much more costly response on an annualized basis but also involve a lot of capital costs we didn't account for. We took the coal switching alternative only for the purposes of this analysis and because we believe it was the least costly approach and we were trying to be as conservative and reasonable in our numbers.

The result of that analysis based on those numbers is the displacement of tonnage and the resulting job dislocation action.

Second, I would agree with Mr. Hawkins that there is the prospect for increased production in those high sulfur coal producing regions over the long run. As his rebuttal indicated, the increased production in Illinois and Indiana will occur not in 1990, but in the year 2000.

What the bill is saying is we have to shut down our mines now as we lose existing business, and our miners have to go somewhere else for 10 years.

We have to try to keep these mines open. I am saying that kind of infrastructure dislocation will be extremely difficult to overcome. Our analysis was based on existing tonnage and what would happen to existing tonnage as a result of coal switching, which is the result of the assumption we use.

Senator RANDOLPH. Mr. Hawkins, I don't want to continue this. He said something you might respond to.

Mr. HAWKINS. One of the things he said, I used shifting. He says on page 9 of his statement, "In addition to the direct mining jobs which would be lost because of these massive production shifts," et cetera.

The second point is that I said th[illegible] are some areas—Illinois, Ohio, Pennsylvania—which will lose t[illegible] production in 1990 compared to today, and there will be a dip in production and it will be until the year 2000 before they are substantially above today's levels.

There is no free lunch. You can avoid those production losses by restricting the least cost techniques in an acid rain reduction bill that will make the total cost of the program somewhat higher, but it is a way of offsetting that.

This is the kind of balancing judgment that Congress is expected to make in our society.

Mr. FARRAND. I think we disagree only on the assumption. I would agree that the application, forced or otherwise, of technological response would have a dampening effect on the job dislocation in the bill as presently constituted.

Senator RANDOLPH. Mr. Chairman, I understand you are leaving for another commitment. As your partner, as we all are in this committee, I want to thank you for the attention you have given to this most important subject, because what affects one State affects another.

What affects a country affects even a contiguous country. So I am very personally appreciative.

Senator STAFFORD. Thank you very much, Senator.

I regret another committee is now meeting.

Senator RANDOLPH [presiding]. Mr. Hawkins, you well know that there are within a State—let's take, West Virginia—two types of mining, not that mining is dissimilar, but the coal that is the basic subject we are talking about is of high sulfur.

There may be intermediates, but low sulfur content. One against the other. Is that correct?

Mr. HAWKINS. That is correct. There are both types of coal, for example, in West Virginia.

Senator RANDOLPH. Now, what happens if the high sulfur coal is closed to its markets?

Mr. HAWKINS. Well, if it were closed to its markets, then those mines would not operate to the extent it was closed. Our assesment is that it will not happen to a large extent, and where it will happen, there will be very large offsetting impacts in increased production from other mines.

Senator RANDOLPH. All right, I will ask this question of both you and Mr. Farrand. We do know there has been many proposals that have to do with what we call general coal-washing requirements as a substitute for or certainly a part of the sulfur dioxide reductions that are called for in Senator Mitchell's bill.

I think that both of you, or one of you, would want to tell us how much reduction in sulfur dioxide could be achieved through this coal washing.

Mr. HAWKINS. Senator Randolph, it depends on whether there are also coal shifts after the washing. If you assume that there are no shifts in coal, then the estimates range between 1.5 to 2.5 million tons of reduction is my recollection.

If there were some shifts in coal so that people burned higher sulfur coal and washed it, you could have no reduction.

Senator RANDOLPH. I believe, Mr. Farrand, as I recall, you have exact figures.

Mr. FARRAND. The data on the exact effect of coal washing is probably not as good as it should be. I can answer the question in two respects.

Peabody's experience in the Midwest shows substantial success in the effects of washing. Peabody washes probably in the neighborhood of 80 percent of the high sulfur coal we mine in the Midwest.

In our washing plants, we get reductions in sulfur dioxide emissions in the average of 27 percent, which is fairly effective. It is effective for certain types of sulfur in the coal and not others. It is effective for pyritic sulfur and not organic sulfur. It also has some side benefits, of course. In certain types of coal increases occur in the Btu content per pound of the washed coal, and it also eliminates some of the ash. It reduces the volumity of the coal. It therefore has benefit in the operation of the boiler, et cetera.

The gross numbers that we have are based on a study completed a few months ago by the Environmental Protection Agency and this study is entitled, "Coal Washing Opportunities in the Midwest." The study covers eight coal producing States, one of which was West Virginia.

They estimated if you had universal washing of coal, you would achieve an incremental reduction of emissions of about 2.8 million tons of SO_2 as a result.

There is a problem in the approach because they assume washing all coal. Certain types of coal that have low percentages of pyretic sulfur are not very cost effective to washing.

I think what we would recommend is a scenario you washed everything from which you could achieve a certain degree of sulfur removal. We have taken a somewhat arbitrary cutoff point and said if the effect of washing is to reduce SO_2 emissions from that coal by less than 15 percent, then it is probably not cost effective. If you can achieve more than 15 percent reduction, it probably is cost effective.

With that we get for those eight States the 2.4 million tons annually of SO_2. So there is a relatively large gain and small cost.

Senator **Randolph**. I will ask both of you, and I must not take too much time, but coal is very important to the country, not only to West Virginia but to New England where it is being burned in our utility plants.

But let's think for a moment of a compromise, if it is that. What would be the reaction of one or more of you to the requirements of washing all coal in the region, to require in addition to that a reduction of 3 million tons of sulfur dioxide each year beyond the reductions required by current implementation plans, but not to impose an immediate cap on emissions in the region.

Do you want to discuss that later in written replies or how would you want to handle it? It is a very important question.

Mr. **Hawkins**. We could respond briefly.

The coalition proposal permits coal washing as one of several techniques to meet the reduction target. Our concern is that a reduction target of 3 million tons simply would not be adequate to take the steps that we need today.

If the Congress feels that reductions on the order of 10 million tons may have impacts that they would like to avoid——

Senator **Randolph**. Did he say 3 million tons a year?

Mr. **Hawkins**. Three million tons a year simply would not be enough to avoid the damages that are accruing today. Our preferred approach would be if there is a concern about the 10-million-ton figure having an impact on economies in coal-producing areas, that it would be more appropriate for Congress to address that and devise a way of alleviating that impact and still get the 10-million-ton reduction.

It can be done. We have given you figures indicating even without that approach we are talking about an average rate increase of 1.9 percent.

If you are going to protect high-sulfur coal-producing jobs, you will add to that total cost. I cannot tell you the exact amount you will add. You will add something and that would be preferable than taking a step which would be inadequate to control this problem.

Mr. **Farrand**. Mr. Chairman, I would prefer to try and respond in more detail at a later time. I do want to correct an impression. I don't think what you are proposing is a 3-million-ton reduction as opposed to 10 million tons, but an additional reduction from the SIP which was estimated to about 1½ million tons and by coal washing, even with the thresholds we have suggested of 2.4, was a 7-million-ton reduction as opposed to a 10-million-ton reduction. That is how I understand the question.

Senator **Randolph**. You are correct, and that is the way the question was asked and your response will be made a part of the record.

We would like to have the utility witness, Mr. Gerstner, reply.

Mr. **Gerstner**. Yes, Senator, the industry is currently making a survey of its own to determine what results could be made from coal washing. You must remember in Mr. Farrand's statement, I believe he said 80 percent of Peabody coal is being washed, high sulfur coal. Now that covers many of the utilities in the area of the

Midwest which are seemingly being singled out by the bills proposed.

Consequently, coal washing in those areas in order to produce the results either Mr. Hawkins or Mr. Farrand are discussing would need to have some trade off basis so that you could be able to get—in other words, the bills would need to authorize a way of intraplant trade off or intrasystem trade off or perhaps even intrastate trade off in order to realize the benefit we are talking about since much of this coal washing is already being done.

Mr. **Farrand**. Mr. Chairman, may I correct one impression. I think about 75 percent of the high sulfur coal in Illinois is currently washed. I don't know what the percentage is in Indiana. We wash all our coal in Indiana. But in Ohio, they wash a relatively small percentage of the coal, so there is a lot of opportunity knowing what we understand and believe the long-range transport would have an effect in your part of the country, Senator Mitchell.

So the opportunities are localized, but as a region the Midwest has a lot of opportunity for saving. As the EPA study shows, they include Indiana, Kentucky, Virginia, Ohio, West Virginia, and Alabama in the numbers I have described earlier.

Mr. **Gerstner**. I think, Senator, some of the examples of what I am trying to say about coal washing and the benefits that can be realized—and I enthusiastically agree benefits can be realized—but in the area we are talking about, including your own State of West Virginia, in part of that State in the last 5-year period coal burning has increased, from 1975 to 1980. In that same period SO_2 emissions have decreased from 977,000 tons to 898,000 tons. Now overall for the Midwest area of Illinois, Indiana, Kentucky, Michigan, Ohio, and that part of West Virginia, there has been an emission decrease of 7,419,000 tons in 1975, down to 6,288,000 in 1980. That is at a time the amount of coal we are burning is up.

Now a large part of that, or certainly a substantial part of that is due to coal washing. These results have already been achieved. So I support that coal washing could very definitely reduce emissions further. But you have to consider how trade offs can be made in that area, as Mr. Farrand and I are both suggesting.

Mr. **Hair**. Senator Randolph, I think it's important as we hear these statements of facts and figures to keep the initial perspective in mind. As we are calling for a 10-million-ton reduction that still does not achieve the goals in the National Academy of Sciences study. We might have put ourselves in a vulnerable position of not requesting more but in these times we think 10 million is economically and initially feasible.

Anything less than that will not meet the economic and environmental goals.

Senator **Randolph**. I am going to address you, Senator, as chairman because I am going to ask you to take over.

Senator **Mitchell**. Ordinarily I would be honored, but seeing how I am the only other person here I see you didn't have much choice.

Senator **Randolph**. Thank you Senator Mitchell. We are going to have to do some more questioning with all of you. This is a matter that is very complex and figures are varying here as you give them. The washing situation, we understood it very, very well.

There might be something in connection with the rate base within the utility, or the beginning of the construction of some of these helps or aids that we have.

Mr. GERSTNER. CWIP in the rate base is very necessary for the kind of capital program you would be discussing if scrubbers were mandated.

Senator RANDOLPH. Well, I thank you, and I wish the answers are easily come by, but they are not.

I again commend all of those who have bills and who cosponsor bills with you, Senator Mitchell. I will not be one that will want to delay, but I shall be one member of the committee that will be careful that we don't move before understanding exactly what we are moving on. The scope of the bill that might be rewritten, are we thinking of across the board, are we thinking of only parts of the Clean Air Act that are now upon the books, the time element that is involved, even with the handling of legislation of this type in the Senate before we go out apparently some time in late December?

I shall not be one that shall advocate delay but I will insist upon thorough discussion, not only continuing questions by mail or in person with to the witnesses, especially this panel, but also in the committee itself.

Having said that, I return to what I said before, that the contamination of the air is something that gives concern not only to business, not only to recreation, not only to all the forests that are involved in the environment, but in the final analysis it is a people problem, and it comes down to the individual who breathes the air. And I must always remember that.

Thank you very much.

Senator MITCHELL [presiding]. Thank you, Mr. Chairman.

I would like to ask just a few questions. Mr. Farrand, I wanted to follow on a point raised in your colloquy with Senator Randolph. You stated at the outset of your prepared statement, evaluating the economic impact on the coal industry, that you assume, and I am now reading, "That in almost every case utilities will choose to substitute fuel rather than retrofit existing facilities."

Therefore the adverse impact on the coal industry is the maximum under this assumption. Is that correct?

Mr. FARRAND. It is probably the least cost to the overall economy.

Senator MITCHELL. Now to the extent, as you candidly acknowledge, that that assumption is invalid, that is, to the extent the utilities choose to retrofit existing facilities rather than substitute fuel, also the adverse impact on the coal industry would be less, would it not?

Mr. FARRAND. Yes, sir.

Senator MITCHELL. It might have a greater adverse effect on the utility industry, but so far as your economic impact is concerned, of course, you sat there while Mr. Gerstner read his statement, so you are aware that his statement contains almost exactly the opposite of your assumption. He has stated that although in certain circumstances sources may elect to shift fuels to comply with emission reductions, there is little doubt in his mind there would be widespread scrubbing. Obviously from his standpoint that is worse, from their standpoint, than switching.

I only want to make the point I think it is clear there are two possible results. The most likely result is some mixture. But you have chosen the result most adverse to the coal industry, and on that assumption of protected adverse economic impact. Mr. Gerstner, for his part, has chosen something directly contrary from the utility industry, because obviously that is the worst, from their standpoint, and has evaluated the impact on this basis.

It is clear, is it not, that both of those extremes cannot occur simultaneously. You cannot have everybody retrofiting to establish the devastating impact that Mr. Gerstner projects and then also have everybody substituting fuels to establish the adverse impact that you suggest. And I mean that as no criticism. You are obviously representing an industry. Mr. Gerstner has responded there are limits to washing and substituting.

Mr. FARRAND. May I respond to that?

Senator MITCHELL. Yes.

Mr. FARRAND. When we began this analysis, after some analysis for the State of Missouri, our goal at the time was to look at consumer prices, not at coal displacement. We had to get to coal displacement to get to the cost. But we hadn't translated it into job dislocations.

We were going to pick the least cost response, and our assumption was based on that, and not what was the worst case for us.

Assuming these two things cannot occur simultaneously, then the cost estimate is going to be somewhere between the $3.2 billion figure we estimate and the $10 and $30 billion range estimate of Mr. Gerstrer. We did our analysis with the idea in mind of looking at it from the consumer standpoint.

Senator MITCHELL. Your statement includes an attachment entitled, "Employment Impacts in Producing States," which lists columns, total jobs lost in each State, and then in the producing States, but you acknowledge in your testimony that to a significant degree these jobs lost would be offset by jobs gained elsewhere. You have not, I gather, prepared an attachment that lists total jobs gained.

Mr. FARRAND. We have not. We do mention in the footnote on the page we assume the remaining tonnage not depicted here would either occur in regions where increased employment would offset or it would occur out of the 31-State region. With the constraint of time, we did not have time to carry it forward. We know if we use the same methods of analysis we used here, we can, to some degree, make some prediction about where the low sulfur employment would gain based on empirical data and experience in coal purchases in 1980. Whether it has any meaning, whether there is a capacity in those regions to supply the kind of coal we are talking about, is very much in doubt.

Senator MITCHELL. If I could ask one more question.

You discussed the method by which you estimated job loss included a multiplier effect. Wouldn't that multiplier effect occur with respect to jobs gained as well as jobs lost?

Mr. FARRAND. Sure.

Senator MITCHELL. Did you want to say something?

Mr. **Hair**. Yes, Senator Mitchell.

There is a part of this economic analysis that is escaping this discussion, and I think it needs to be considered in this discussion, and although there clearly will be economic impacts on the regions in which controls will be placed, the economic impacts on the regions in which the emissions will have their negative environmental effects both on the natural resources as well as human health are also profound. And I would use the rather simplistic analysis, if we consider domestic garbage and how we resolve the control of domestic garbage, do we pay to have it removed by cities and townships or is it in fact cheaper just to throw it in our neighbor's next door yard? We know the answer. Should not those States that are going to attract those kinds of industries for which these kinds of results occur be expected to pay some of the burdens? The economics is two-sided, it goes to both ends of the spectrum.

Mr. **Farrand**. I am not suggesting that industry or the utility sector or consuming public which pays for that electricity should not and is not willing to pay the cost.

In fact, the mechanism the Congress already has in place to deal with the loading problem, which is the new source performance standard, bears with it a considerable cost, which we and the utilities, and ultimately the consuming public, has accepted. And it is a very sizable number.

The total cost for complying with the new source performance standards as promulgated by EPA is in the neighborhood of $37 billion. Now, that is to get the loadings down. But it does it in a form which is not disruptive to the present economy. You are not attacking or changing coal supplies or changing or trying to add capital cost to plants where you can get no increase in production. You are doing it where you replace existing facilities with new ones. If you can find a way to do it without severe impact to the consuming public, maybe that would be the ultimate solution. You can have trade-offs such as increased plant efficiencies. The public has accepted that. So it is not as if we are trying to ignore or walk away from it. We see a much more equitable or less disruptive approach in using that, or something and that and coal washing, than going with an extremely disruptive approach that says you have to do it in the next 8 years.

Mr. **Hawkins**. The new source performance standards are very important to keep new sources from increasing our problem. But our problem today is existing sources and the combination of existing and new sources throughout the rest of this century, according to the latest predictions, will produce greater sulfur dioxide emissions in the year 2000 than are emitted today from utilities. Only after the year 2000 and only assuming retirement rates which we cannot verify empirically because we don't have the history of when large plants built in the fifties are going to retire, only after the year 2000 is there a prospect of reduction in utility sulfur dioxide emission simply due to the turnover.

Senator **Mitchell**. If I could just say, Mr. Farrand, you stated something that caught my attention. You said the people most concerned are not going to pay. And I really don't want to be argumentative with you, but the people most concerned are paying now.

You mentioned trout fishing. Trout cannot reproduce in streams in Maine above 2,000 feet. After decades of struggling, we have been able to reintroduce Atlantic salmon back into Maine with positive effects. And it is not just environmental. This is an important part of our economy. Sport fishing is a major industry in Maine, as it is in the other States. So I understand what you are saying, and you are obviously a very thoughtful person, that you don't see the link between the emissions and the damage, at least not conclusively as a problem. That obviously is the question that troubles everyone here. Where that link established conclusively, to your satisfaction, I don't think we would be even discussing this bill.

Mr. **Farrand**. I don't deny the damage. I certainly don't deny the damage. I think when you anticipate cost of the magnitude we are talking about in this bill, you had better be certain there is a link, and that is all I am saying.

Senator **Mitchell**. I understand that and appreciate that. Frankly, the National Academy of Sciences report I found to be very compelling, and it is an objective, prestigious body, which I think has no stake in this other than to do something in the name of, to use Mrs. Bennett's words, sound science.

Well, I thank you gentlemen very much. It has been a long hearing and we appreciate your patience.

The committee will stand in recess.

[Whereupon, at 2:10 p.m., the committee adjourned subject to call of the Chair.]

[Statements and other material submitted for the record and the bills S. 1706, S. 1709, and S. 1718 follow:]

[illegible] GARN, UTAH, CHAIRMAN

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United States Senate
COMMITTEE ON BANKING, HOUSING, AND
URBAN AFFAIRS
WASHINGTON, D.C. 20510

October 15, 1981

The Honorable Robert Stafford, Chairman
Committee on Environment and Public Works
United States Senate
Washington, D.C. 20510

Dear Mr. ~~Chairman~~ Bob:

I would like to submit, for your consideration, a statement of my views on the upcoming reauthorization of the Clean Air Act.

I know you share my deep concern about many of the proposals that have been put forward that would weaken the Act and extend indefinitely the exposure of the American people to levels of air pollution that threaten their health and welfare. While you, both as Chairman of the Committee on Environment and Public Works and as Co-Chairman of the National Commission on Air Quality, have identified a number of changes to the Act that are needed to make it work more efficiently, I think you will agree that the Act's protections should not be weakened nor its enforceability undermined.

Of particular concern to me in light of recent activities is the effort to double the allowable emissions of carbon monoxide and nitrogen oxides from automobiles. As you may know, automobile emissions constitute the greatest air pollution threat to the people of Connecticut and those of other densely populated areas. A relaxation of auto emission standards would make it impossible for Connecticut to meet the air quality standards for ozone and carbon monoxide by 1987 thereby subjecting thousands of the people of my state to unacceptable health risks. Even if automobile industry claims of savings of a few hundred dollars per car are accurate, such savings are not worth the cost, in terms of lives and ill health, to the millions of Americans who would suffer from higher levels of pollution.

I would also like to urge your support for an amendment I recently introduced with Senator Durenberger to revise the interstate pollution sections of the Act. Enclosed with my statement is a copy of that proposed amendment, introduced as S. 1718, which I hope you will give careful consideration as your committee marks-up the Clean Air Act revisions.

Thank you for your consideration of my views on this important piece of legislation. I look forward to continuing to work with you and other members of the committee as the bill moves forward.

Sincerely,

CHRISTOPHER J. DODD
United States Senator

cc: The Honorable Jennings Randolph

STATEMENT OF
SENATOR CHRISTOPHER J. DODD

The Clean Air Act

Overview

Mr. Chairman, among the major legislative tasks before the Congress this year is the reauthorization of the Clean Air Act. As you know, preparation for this reauthorization has been extensive. A comprehensive review of the Act by the National Commission on air quality was recently completed after 30 months of intensive study. The Commission's final report, issued in March of this year made numerous recommendations. It is significant that the Commission's basic conclusion was that the Clean Air Act is working effectively in most aspects and does not need major restructuring. The 23 days of hearings that have already been conducted by this Committee have largely supported this conclusion.

The Clean Air Act has brought about significant improvements in the nation's general air quality during the past decade. Nationwide between 1973 and 1978, there was a 20 percent reduction in annual concentrations of sulfur dioxide and a 7 percent reduction in total suspended particulate matter. These are among the more pervasive pollutants and have been strongly associated with aggravating the symptons of heart and lung diseases and with causing acute respiratory diseases and reduced lung function in children.

My own state of Connecticut, which has the most stringent sulfur standards in the nation, has realized even greater progress, and has reduced sulfur dioxide levels to well below those that seriously jeopardize public health and welfare. Connecticut also made significant progress in reducing particulate levels during the early 1970's. More recently this progress has slowed and while particulate levels across most of the state are below those that seriously jeopardize human health, further progress will be needed in the years ahead to adequately protect the people of Connecticut from adverse effects of this pollutant.

During the 1973 through 1978 period, concentrations of carbon monoxide declined by 33 percent nationwide. Carbon monoxide, the primary source of which is automobile emissions, aggravates circulatory problems and heart disease. Carbon monoxide has also been shown to have adverse effects on the function of the central nervous system.

Since more than 95 percent of the carbon monoxide emissions in the state of Connecticut come from motor vehicles, progress toward reducing CO levels is dependent on reductions in auto emmissions of this pollutant. Levels of carbon monoxide in excess of the national health standard are still common in many areas of Connecticut, making automobile pollution control improvements a continuing priority for the people of my state.

We are making progress. But this progress does not lead to the conclusion that the Clean Air Act has done its work and may now be relaxed. The Air Quality Commission concluded that, "the prognosis for the 1980's reflects a need for the control of air pollution to be a continued national priority," and that during the 1980's millions of people will continue to live in areas exceeding healthful levels of air quality.

Economic Impact

Chief among the arguments of those calling for significant relaxations of air pollution rules is the assertion that further control of air pollution is too expensive to justify the investment. I know of no one who argues that cost considerations are not important. Every effort should be made to minimize the costs of attaining clean air. A healthy economic environment is as vital to human welfare as is a healthy physical environment.

The fact is, continued progress toward clean air has not had and is not projected to have a significant retarding effect on the American economy. The National Air Quality Commission concluded that, "the effect of the Act's requirements on national economic indicators has not been significant, and is not expected to be significant through the period for which projections are available, the mid-1980's."

In fact, studies of the economic impact of pollution control programs have either shown no significant impact or positive impacts on gross national product, productivity and jobs.

The most recent study of the economic impact of our environmental laws, performed for the Environmental Protection Agency by Data Resources, Inc., showed essentially no impact on potential gross national product or productivity. A 1981 Public Interest Economic Foundation study also showed that today the GNP is essentially unchanged as a result of the Act. Compliance expenditures for air pollution control are estimated to have accounted for about 3 percent of industry's total capital investment during the decade since passage of the Clean Air Act of 1970. In addition, these expenditures have remained stable in real terms since 1975.

Concerning jobs, the Council on Environmental Quality has consistently concluded that pollution control outlays have a positive impact on employment. Estimates range from 70,000 to more than 80,000 jobs created for every $1 billion spent on pollution control.

Overall, unemployment has been .1 to .2 percent lower per year than it would have been without the Clean Air Act. The DRI study projected nationwide unemployment at .3 percent less during the period 1970 through 1987 because of jobs created by environmental control requirements.

While some industries, companies and localities may have borne a greater than average burden under the Clean Air Act, there is little evidence that this has been overwhelming. In five years of monitoring for localized economic dislocations, the Environmental Protection Agency has found only a handful of plant closings genuinely attributable to Clean Air requirements. Such monitoring should continue and where substantial dislocations are determined to be the result of pollution control requirements, adjustment assistance should be provided. This localized approach is clearly preferable to a general relaxation of air quality standards.

Nor have the Congress or the Environmental Protection Agency been insensitive to the needs and burdens of those industries or localities which have incurred heavy pollution control costs. Deadline modifications and case by case waivers have been extended on numerous occasions. Special legislation for the steel industry has received Congressional approval already this year. The Steel Industry Compliance Extension Act of 1981 will, in fact, result in both cleaner air and modernization of many of the less productive and uncompetitive steel facilities in existing steel communities. This will protect both jobs and health in these communities.

Some have also argued that rules to prevent significant air quality deterioration in clean air areas have stifled economic growth. Studies conducted for the Commission on Air Quality found that there is virtually no evidence that approvals have been denied for new or expanded facilities wishing to locate in such areas.

On balance, a picture emerges that contains much cause for optimism that we can make and are making progress toward re-establishing a healthy level of air quality for the people of this nation. Nor does that picture depict dramatic economic sacrifices that must be made in order to continue this progress. I urge the Committee to keep in mind that large segments of our population, particularly those in major metropolitan areas, live in areas that have not yet achieved healthy air; that millions of our elderly and children and others with chronic respiratory and heart ailments frequently cannot participate in normal outdoor activities because of dangerous air pollution levels.

These people have a right to an environment in which they can safely walk outdoors, in which they can live their lives to the fullest without the fear of being incapacitated, even temporarily, by simply breathing the air around them. This Committee and this Congress have the responsibility to grant them that right and to preserve it. A strong, enforcable Clean Air Act is the only mechanism for insuring that our progress toward clean air is continued.

Cost-Benefit Analysis

Through a decade of experience with clean air legislation we have gained substantial knowledge. Still, the state of our knowledge about public health and welfare benefits of reduced pollution is imperfect. This uncertainty is not new nor is it likely to disappear in the foreseeable future. Yet, uncertainty is no excuse for inaction. If it were, there would be no Clean Air Act.

On this point, the Air Quality Commission concluded that, "to protect public health, government must act to control potentially harmful pollutants despite scientific uncertainity about the precise harm they cause and levels of exposure that cause harm."

As I have stated, the protection of public health and welfare from the adverse effects of air pollution should be carried out as efficiently and as equitably as possible. Among the major issues addressed thus far in this Committee's hearings on the Clean Air Act is the application of cost-benefit analysis to clean air decisions. While some have suggested that costs be given significant weight in setting health standards, most witnesses have concurred with the Air Quality Commissions finding that, "the costs of meeting primary air quality standards are best taken into account in determining what control programs should be implemented in specific areas of the country, not in establishing a national standard to protect public health." To use cost-benefit analysis in establishing the "primary" health related standards would place government in the position of attempting to equate the value of human life with the value of the goods and services produced by polluting industries. Such a judgment is neither appropriate nor practical and should be rejected by this Committee, this Administration, and this Congress.

The application of cost-benefit analysis to the so-called "secondary" standards, those designed to protect other environmentally affected values such as crops, wildlife, forests, buildings, visibility and other economic and quality of life variables, is likewise difficult to implement. Many of these values are no more readily subject to formal cost-benefit analysis than is human health. The same holds for establishing the value of preventing the deterioration of relatively clean air. Current rules are designed both to preserve clean air where it exists and to prevent clean air areas from bidding industry and jobs away from more polluted areas by allowing firms to operate with more pollution and lower costs.

As a result of this balanced approach, overall air quality has been maintained or enhanced in most areas without creating major economic dislocations and inequities among different regions of the country. These principles of nondegradation and economic equity are critical to preserving both environmental values, and balanced economic growth under our clean air laws and should be preserved in this year's reauthorization of the Act. Cost-benefit analysis should continue to be used in evaluating alternative control strategies and in setting timetables for meeting standards.

The Need for Flexibility

There is also substantial evidence that the Environmental Protection Agency should exercise greater flexibility in its oversight of state clean air implementation plans. The Clean

Air Act establishes the states as the primary agents for achieving clean air goals. The states must submit to the EPA their plans for achieving those goals. Many states have complained that the "federal-state partnership" envisioned by the Congress under the Clean Air Act could better be characterized as a "federal big-brother-state relationship."

I do not believe it is either necessary or desirable for the federal EPA to review and approve every detail of a state's program to implement the Clean Air Act. Greater flexibility needs to be given to the individual states to respond to their own needs and to implement their clean air efforts with flexibility and a minimum of federal duplication.

Likewise, industry should be given greater flexibility in selecting the most appropriate and most efficient approach to addressing its air pollution problems. Experimentation with "performance standards" has, in some cases, yielded significant savings without sacrifice in movement toward clean air objectives. These efforts should be continued and enhanced.

The law should make clear, however, that such flexibility is not a license to ignore clean air goals. It is not an endorsement of unwarranted delay in reducing pollution emissions Most importantly, it does not sanction noncompliance with air quality or emission standards determined necessary and desirable for the protection of public health and welfare.

Interstate Transport of Pollution

Among the major justifications for federal action on air pollution is the fact that pollution does not respect political boundaries. Emissions from power plants in Connecticut do not stop at the state line. Likewise, emissions from automobiles in New York City metropolitan area show no hesitancy to enter Connecticut when the prevailing winds are from the southwest, as they frequently are.

The Air Quality Commission recognized the weakness of the Clean Air Act in dealing with the problems of interstate transport of air pollution. One of the Commission's chief recommendations for changing the Act was that, "the interstate pollution abatement provision of the Act ..should be modified to strengthen provisions requiring a state to reduce emissions which affect other states and to provide more useful criteria for a state to use in showing that emissions from sources in another state adversely affect it."

Section 110 of the Act requires each state's implementation plan to include provisions to prohibit any stationary source of pollution in the state from producing emissions that will, "prevent attainment or maintenance" of air quality standards in another state. Section 126 allows a state or local government to petition EPA to require emissions reductions from a source in another state that violates the prohibition in Section 110.

Last year Connecticut filed two Section 126 petitions with the EPA in attempts to prevent harmful levels of sulfur dioxide emissions that drift into Connecticut from power plants on Long Island. New York state and Pennsylvania have each filed petitions with the EPA requesting that excessive emissions in neighboring states be reduced. A similar request was filed by the state of Kentucky in an effort to reduce harmful emissions from a power plant in Indiana.

In spite of the fact that several of these petitions were filed more than a year ago, none were acted on by the EPA until July 30, 1981, at which time the Kentucky petition was acted on. In the case of Connecticut's two petitions, the EPA proceeded to approve the Long Island power plants' plans without consideration of Connecticut's petitions in spite of the fact that the Clean Air Act requires the EPA to present a finding on Section 126 petitions within 60 days of their submission.

If any sections of the Clean Air Act should recieve greater federal attention, it is these sections that protect the people of one state from pollution generated in another area over which their own state government has no control.

As I have mentioned, Connecticut has the strictest sulfur dioxide emissions standards of any state. Of the near 30 million tons of sulfur dioxide emitted into the atmosphere annually in the United States, less than 100,000 tons are discharged from sources in Connecticut. Yet the Clean Air Act and the EPA allow neighboring states to emit significantly higher levels of this pollutant in a manner that has adverse effects on Connecticut.

While Connecticut meets the national ambient air quality standards for sulfur dioxide, the transport of SO_2 from sources in New York and other areas to the southwest reduce Connecticut's economic growth potential and raise the costs of operating industries in Connecticut. The highest levels of SO_2 in Connecticut generally occur in the winter months. This is partially due to the increased combustion of fossil fuels during these months but this increase does not account for all of the increase in measured SO_2 levels. Also associated with winter months and with the highest measurements of SO_2 in my state are persistent southwest winds. These winds pick up sulfur dioxide over the New York City metropolitan area and transport them into Connecticut. Subsequently, under clean air rules, Connecticut industries face more severe constraints on their allowable sulfur dioxide emissions than they otherwise would if Connecticut air were not receiving pollution from outside the state.

Under current law, the EPA, thus far, has not determined that a clear violation of Section 110 results from this type of harm. The chief cause of this is that present requirements, based on local pollution concentrations, do not reflect consideration of low level cumulative effects of pollutants that are transported up to hundreds of miles from the source. Because the control emphasis has been on local, ground-level effects, sources have had an incentive to disperse pollutants away from the local area through the use of such techniques as tall stacks. This "exporting" of pollution contributes to the long-range transport problem and imposes greater burdens on areas that have addressed pollution problems by reducing emissions.

Further complicating the problem is the assertion by some that Section 126 of the Act requires that a downwind state demonstrate that attainment of its air quality standards is being "prevented" by emissions from a particular source in another state. While an aggregate of sources in the upwind state may meet this criterion, measurable adverse effects of pollution from a single source in another state are extremely difficult to demonstrate. The Air Quality Commission has recommended that Section 126 be changed to clarify that a state may petition EPA for a finding that such an aggregate of sources as well as any single source in another state violates the Act's interstate pollution requirements.

A similar change is needed with respect to pollutants from mobile sources. Suspended particulates, ozone and nitrogen dioxide derive largely from highly dispersed sources, in particular, sources related to automobile use. Such sources are not presently covered by Section 110 of the Clean Air Act, yet they also create significant interstate pollution problems. For all of these pollutants, Connecticut's 1978 Air Quality Summary showed that the highest concentrations, some high enough to violate health standards, occurred on days when the prevailing winds were from the southwest, the direction of the New York City metropolitan area.

This problem is not unique to Connecticut. Practically every state confronts the same dilemma--how to control pollution emissions from another state. Only federal intervention can adequately address this problem. It is a problem that must be approached with reasoned consideration of the constraints, both economic and technological, faced by all states. But the fact that current law is totally ineffective in bringing about equitable resolutions of interstate air pollution transport problems demands strengthening of these provisions.

I introduced _________, with Senator Mitchell of this Committee, an amendment which I believe will correct these weaknesses and inequities in the Act's current language concerning interstate air pollution. A copy of our amendment is attached to this testimony and I strongly urge the Committee to adopt its provisions.

Acid Rain

A related, and perhaps even more difficult, long-range transport problem identified by the Air Quality Commission is that of acid rain. The current Clean Air Act simply does not address the acid rain problem. Again, the focus on local ambient air pollution concentrations ignores the long-term and cumulative effects of widespread atmospheric pollution. In the case of acid rain, the problem is compounded by the tremendous distances over which pollutants often travel and the fact that several chemical transformations occur in the process of long-range transport of these pollutants.

While there remain many uncertainties surrounding the causes and effects of acid rain, the evidence we do have is cause for serious concern, particularly in New England and several other vulnerable regions of the country.

In addition, the Canadian government regards acid deposition as its most critical environmental problem. A recent memorandum of intent between the United States and Canada commits both countries to efforts to reduce the potential for transboundary pollution. Strengthening the Clean Air Act this year is essential to our meeting this international commitment.

The problem of acid rain is not, as some argue, purely hypothetical. Substantial evidence exists that acid deposition, both in rain and dry deposition through gases and particulate matter, has resulted in the disappearance of fish from up to 200 high altitude lakes in the Adirondak area of New York. Similar evidence exists with regard to thousands of fishless lakes in the Canadian Province of Ontario and in Sweden. Several thousand lakes in Minnesota and Wisconsin and additional 48,000 lakes in Ontario alone are considered susceptible to increased acid levels.

Evidence is also mounting that acid rain damages the productivity of soils, affecting both crop yields and forest growth while research has indicated that there are at times positive effects on crop and forest growth from higher levels of sulfur, nitrates and ammonia in precipitation, the opposite is true in sensitive areas where soils are not well buffered by acid neutralizing elements.

The sensitive regions in North America include New England, parts of New York, large areas of Ontario, Quebec, and the marittime provinces of Canada, northern Minnesota, Wisconsin, and Michigan, most of Washington, Oregon and Idaho, and parts of the Appalachia region, Florida, California, Colorado, Montana, Wyoming, Nevada and Missouri.

Acid deposition has been shown to increase the rate of leaching from soils of numerous heavy metals, some of which, in heavier concentrations than normal are toxic to both aquatic life and plants. Heavier toxic metals leaching into water supplies may also pose human health threats.

Acid deposition has also been linked to damage of building materials, creating not only substantial economic losses through more frequent repairs, but also endangering many of the nation's historic buildings and monuments, many of which lie in the northeast where the greatest amount of acid deposition takes place. Increased corrosion of copper water piping and of lead soldered joints has also been shown to result from more acidic water supplies.

In spite of the many unknowns regarding acid rain, its formation has been firmly linked to levels of sulfur dioxide and nitrogen oxides in the atmosphere. We also know that 90 to 95 percent of the sulfur emissions in eastern North America are from man-made sources.

The Air Quality Commission determined that the problem of acid deposition is severe enough and that enough is known to recommend that the Congress require a significant reduction, by 1990, in the level of sulfur dioxide emissions in the eastern United States. A substantial reduction in sulfur dioxide emissions in the east is particularly important in light of the fact that, under present control technologies, nitrogen oxide emissions are projected to continue to increase during the next decade.

Connecticut, like other New England states and eastern Canada, is at the end of the pollution pipeline in this country. Our problems with acid rain and the long-range transport of air pollution are perhaps more severe than other sections of the country. I believe it is clear, however, that no state is immune from these problems. It is also clear that the more we learn about them, the more severe the consequences appear.

I urge the Committee to address this common problem substatively as we proceed with the Clean Air Act Amendments of 1981. Further research is needed and at an accelerated pace. But our current knowledge as well as our commitments to Canada provide a sound basis for further actions to reduce sulfur dioxide emissions, particularly in the eastern half of the United States.

I believe the Acid Deposition Control Act, S.1706, recently introduced by Senator Mitchell, me and others provides a sound basis for addressing the problems of acid deposition and urge the Committee to adopt this proposal as an amendment to the Clean Air Act.

Many of the identified effects of acid rain are irreversable. Delay in addressing the principle known causes of this phenomenon would subject the people and the resources of vulnerable areas of totally unacceptable risks.

Conslusion

When the hazards of environmental degredation broke upon the American consciousness nearly two decades ago, public confidence in government's commitment to protecting the general welfare was dealt a severe blow. For more than a decade the Clean Air Act has been a keystone in the effort to restore public confidence in government as the servant of the people rather than the servant of narrow special interests. If this Congress shrinks from its responsibility to preserve and enhance public health and general environmental quality, it will rightly be condemned for its gross breach of trust. The Clean Air Act remains a keystone in the effort to restore public confidence in government. I am confident that the American people will not passively tolerate either a Congressional or an administrative dismantling of this vital legislation.

The Connecticut Chapter
of the Sierra Club

October 27, 1981

Senator Christopher J. Dodd
337 Russell Senate Office Building
Washington, D.C. 20510

Dear Senator Dodd:

The Connecticut Chapter of the Sierra Club strongly supports your bill, S. 1718, to amend the Clean Air Act. Clearly a provision in the Act to address the problem of long range transport of air pollutants is needed.

The Connecticut Chapter agrees that a strong federal law to protect states from pollution generated in other states must be established. Even with strict air pollution controls, Connecticut continues to suffer from high levels of background pollution from other states. Not only does this situation present a health hazard for residents, but industries in the state must compensate by burning cleaner, more expensive fuel, putting them at a competitive disadvantage.

S. 1718 offers an equitable solution to the problem of long range transport of air pollutants. The Connecticut Chapter applauds your efforts to strengthen the Clean Air Act in this area.

Sincerely,
B Holly Schadler
B. Holly Schadler
Director

cc: Governor William O'Neill

10/29/81

STATUS OF 126 PETITIONS

Petitioner(s)	Power Plant(s)	Location	Date Petition(s) Filed	Date Hearing Held	Current Status
West Virginia	Sammis	Ohio	Fall 1978	No Hearing	Being resolved through SIP and enforcement processes.
Kentucky	Clifty Creek	Indiana	12/78	6/79	No findings yet proposed. Action currently underway through SIP process.
Kentucky (Jefferson County)	Gallagher	Indiana	5/79	4/80	7/81 - Publication of proposed determination to deny petition.
New Jersey and Connecticut	Arthur Kill and Ravenswood	New York	4/80	12/80	No findings yet proposed.
Connecticut	Northport and Port Jefferson	New York	8/80	12/80	No findings yet proposed.
New York	19 power plants	IL, IN, MI, OH, TN, WV	12/80 1/81	6/81	Public hearing comment period to close 1/4/82. Draft recommendation to accept or deny the petitions scheduled for Spring 1982.
Pennsylvania	38 power and industrial sources	Ohio, West Virginia	12/80	6/81	See New York status above.

WILLIAM A O'NEILL
GOVERNOR

STATE OF CONNECTICUT
EXECUTIVE CHAMBERS
HARTFORD

October 14, 1981

Honorable Christopher J. Dodd
United States Senator
363 Russell Senate Office Building
Washington, D.C. 20510

Dear Chris:

I want to extend to you my full support of the legislation you have introduced to address the problem of interstate air pollution.

As you are well aware, this is one of the state's most serious problems as current statutory language prevents the state from restricting the flow of pollutants into the state from outside sources. Because of our obligation to limit total pollution emissions and our inability to control out of state sources, economic development in Connecticut is unfairly restrained and the public health and welfare is jeopardized.

I look forward to working with you toward the enactment of your proposal. The Connecticut Department of Environmental Protection has worked effectively with industry and the public in general to insure the optimum benefit of the Clean Air Act State Implementation Plan. I am certain that our efforts will result in a solid foundation of support from those who would be affected by your proposal.

Sincerely,

WILLIAM A. O'NEILL
Governor

State of Connecticut

CARL R. AJELLO
ATTORNEY GENERAL

Office of The Attorney General
30 TRINITY STREET
HARTFORD 06115

October 23, 1981

The Honorable Christopher J. Dodd
United States Senate
Washington, D.C. 20510

Re: Senate Bill 1718 - Revisions to the Interstate Provisions of the Clean Air Act

Dear Senator Dodd:

I wish to offer my endorsement of your bill to revise Section 110 and Section 126 of the Clean Air Act as they relate to interstate pollution.

Connecticut has been forced to litigate under these sections requesting that a neighboring State and the Administrator, United States Environmental Protection Agency, consider Connecticut's air quality when it approves a revision to a state implementation plan allowing the use of higher sulfur content fuel oils.

This litigation is necessary because of the apparent lack of a definitive mandate in the Clean Air Act or weak interpretation and implementation of the Act by the United States Environmental Protection Agency, or both, which has resulted in inequitable enforcement of the laws with significant adverse health, economic and environmental effects on the State of Connecticut. Your proposed revisions will force the United States Environmental Protection Agency to meaningfully address this issue.

Your proposed legislation complements the legislation which the Eastern Attorneys General have proposed on the Interstate Provisions of the Clean Air Act and will present to Senator Stafford for consideration by the Senate Committee on the Environment and Public Works.

I appreciate the interest you are taking on this crucial problem being faced by the Northeast States, and particularly Connecticut.

Very truly yours,

Carl Ajello

CARL R. AJELLO
ATTORNEY GENERAL

CRA:rb

cc:
The Honorable William A. O'Neill

The Honorable Lowell P. Weicker, Jr.

The Honorable Sam Gejdenson

The Honorable Lawrence J. DeNardis

The Honorable Stewart B. McKinney

The Honorable William R. Ratchford

The Honorable Anthony Toby Moffett

C. Raymond Marvin, Executive Director,
National Association of Attorneys General

STATEMENT OF

GOVERNOR JOHN D. ROCKEFELLER IV

I appreciate very much the opportunity to submit a statement for the record describing the views of the National Governors' Association on the problems of acid rain and the long range transport of air pollution. As the Chairman of the NGA's Energy and Environment Committee, I have overseen the development of the Governors' comprehensive recommendations on the Clean Air Act. In our deliberations on the Act, few issues have generated more interest and debate than the interstate transport of air pollutants. The problem of air pollutants which travel across state lines raises complex and fundamental questions about our approach to clean air regulation. It is not an exaggeration to say that my fellow Governors and I believe the interstate transport problem to be one of the more important and difficult issues facing this nation today.

Before I make specific comments on the various bills which have been introduced on acid rain, I would like to describe the Governors' views on this problem generally.

In their debate of the interstate transport issue, which was extensive and involved consultations with experts from both the business and environmental communities, the Governors were persuaded that part of the difficulty in addressing the long range transport problem is the widespread misconception that it is synonymous with the phenomenon known as acid rain. While there is a growing body of evidence that the acid rain problem is real and very serious, the interstate transport problem is broader than acid rain. The interstate transport problem includes, for example, the transport of ozone and other auto related pollutants, and affects virtually every region of the country. The basic problem stems from the lack of an effective mechanism for dealing with the conflicting interests that arise when air pollution originating in one jurisdiction affects other jurisdictions having no control over those sources of pollution. The heart of the issue, in other words, is the lack of an effective mechanism or institution for bringing the states together in a forum conducive to conflict resolution.

The Governors do not believe that adjudicatory proceedings should be the first resort in resolving interstate pollution problems. Before appealing to a third party, as under Section 126, the states should have the first responsibility and authority for directly resolving interstate disputes. This can be accomplished by having the Congress designate the major interstate pollution corridors, including both source and receptor states, and giving those states a reasonable period of time to agree upon mutually acceptable measures to mitigate the problem. The Governors believe that these negotiations should involve the determination of cost effective measures to alleviate interstate pollution, as well as the resolution of more difficult questions such as how such control measures will be financed. For example, in the case of acid rain, I believe Governors from the region might well agree to implement coal washing as a first phase in addressing the issue.

If after a reasonable period of time, the states in such a corridor have not reached an accommodation on the long-range transport problem, the Governors believe the Environmental Protection Agency should be directed to take action necessary to alleviate the problem. In cases such as acid rain, the Congress should probably specify an overall reduction target for SO_2 and NO_x that EPA could enforce if the states fail to make progress toward that target through the negotiation process. In the case of less well-defined problems such as ozone transport from the LA Basin to southern Nevada and Utah, reliance on a strengthened section 126 proceeding might be preferable to direct specification of a reduction target by Congress. The Governors are convinced that the threat of such federal action and the spotlight of regional or national attention will be strong inducements for all parties in the designated corridors to negotiate in good faith.

We believe that the Governors' recommendation on long-range transport offers a number of distinct advantages over proposals for a direct regulatory program aimed at acid rain. First the NGA proposal is broader than acid rain, and could be applied to any particular part of the country. By addressing an institutional shortcoming in the Clean Air Act, it offers a process for resolving a wide range of transport problems.

Second, the NGA recommendation for regional corridors does not require the degree of certainty over causes and effects that would seem to be prudent for the justification of a federal regulatory program. Rather than mandating the creation today of a full-blown federal regulatory program in the face of continuing scientific uncertainty, the Governors' recommendation could proceed step-by-step, with negotiations among states on additional strategies or control levels moving hand-in-hand with an increasing understanding of the problem. As it becomes more clear that higher levels of control are necessary and effective, these can be adopted through negotiation by the states.

The bill introduced by Senator Mitchell, S. 1706, contains many elements compatible with the Governors' recommendations, and clearly reflects a major effort to deal with the acid rain problem. I personally prefer this bill as a starting point for mark-up rather than other more complex approaches now before the Committee. However, I believe that a number of key changes should be made in the Mitchell bill. Perhaps most important, I believe it is essential that the legislation not mandate state specific emission reduction targets because this will undermine the negotiation process. States who know they face a very small reduction target under the federal plan will have little incentive to join in good-faith negotiations over cost-sharing and other issues.

The overall emission reduction target itself must be more carefully crafted, both with regard to its size and its application. It may be that a 10 million ton reduction in regional SO_2 is the proper target, or that may be very much more than necessary. The Governors have not yet addressed the exact size of such a target. I would agree that the bill needs to establish an emissions reduction target, but I feel that the legislation should specify it as a goal that can be reached in stages rather than being implemented as a mandatory program after two years. The states should be encouraged to agree to a phased approach where known cost effective measures like coal washing can be implemented first, perhaps to be followed by least emissions dispatching and cost-effective retrofits. The federal "club" should be implemented only if states fail to make progress toward the reduction target. As this process develops, research results can be taken into account and states can decide to alter the pace of reductions. Congress can also raise the goal as needed. In this way, control strategies could develop in step with our understanding of the problem.

Another needed change in S. 1706 would be to eliminate the emissions cap imposed by section 182(a) and make it clear than any emissions reduction goal is a net reduction to be achieved over time. The effect of imposing such a cap - unintended, I believe - is to make the entire region non-attainment for SO_2 and NO_x. This would require offsets for new sources and would seriously compromise the flexibility states need to find the most cost-effective emissions reduction strategies.

I would also suggest that the Congress look carefully at the issue of which states to include in the acid rain region. The NGA proposal for interstate transport corridors envisioned a smaller, more targetted corridor or even a number of such corridors. While the Governors have not as yet specifically addressed which states should be included, it is my feeling that a 31-state region would be too large to be workable and would include several states that are marginal contributors or recipients. We will provide you with a specific recommendation shortly on this issue.

In summary, I urge the Committee to proceed cautiously with legislation to strengthen section 126 and to adopt a regional, state-oriented approach to mitigating the problem of long range transport. In offering our own recommendations on this problem, the Governors recognize the need to begin now with a moderate program that can correct the institutional shortcomings of the Act and can provide the states affected by long-range transport problems an adequate opportunity to resolve them before federal action is required.

STATE OF MAINE
OFFICE OF THE GOVERNOR
AUGUSTA, MAINE
04333

JOSEPH E. BRENNAN
GOVERNOR

October 27, 1981

Honorable George Mitchell
United States Senator
344 Russell Senate Office Building
Washington, D.C. 20510

Dear George:

I appreciate the invitation to testify before the Senate Committee on the Environment and Public Works on your proposed amendment to the Clean Air Act designed to address the insidious problem of acid rain. Unfortunately I am prevented from attending the hearing by other commitments within Maine. I would appreciate your including this letter in the official record of the hearing so that my support for your efforts will be reflected there.

My concern about the impact of long range transport problems, particularly acid rain, was expressed before a hearing which you chaired in Augusta, Maine on April 14, 1981. Since my views on the nature and impact of the problem haven't changed, I have attached a copy of that testimony for this record.

Your amendment is designed to start a process of systemic reduction in SO_2 emissions in those states East of the Mississippi which are the primary source of sulfur compounds in our air. It seems to me that an equitable distribution of this burden is not only reasonable but should be insisted upon by those states which, like Maine, are doing their share now. As evidence of our efforts in this regard please note that:

1. Maine has not allowed the construction of tall stacks. It has only allowed stack height increases up to reasonable Good Engineering Practice levels. This is the level just high enough to stop the downwash problems of short stacks located next to tall buildings, but is not so high as to enhance the dispersion by using a super tall stack.

2. Maine has restricted sulfur in fuels to a moderate level and has not allowed increases in sulfur emissions over those allowed with oil when sources convert to coal. Attached is a graph showing emissions to sulfur dioxide emissions of states east of the Mississippi, and a list of various coal burning utility

plants and their allowed sulfur dioxide emission limitations. Maine's limitation is 2.66 lbs./10^6 BTU. These sources are allowed two to three times as much sulfur dioxide emissions as those allowed from a comparable source in Maine.

3. Maine has examined new coal burning sources carefully and in some cases required lower sulfur emissions than would be allowed by federal standards. This is especially necessary since the federal administration is delaying revising some very old sulfur limitations for industrial boilers.

4. Maine has written to the federal Environmental Protection Agency urging the administrator not to allow increases in sulfur dioxide emissions for certain plants already allowed high emissions. We specifically responded negatively to EPA's proposals to allow increases in two Ohio electric generating plants owned by the Cleveland Electric Aluminating Company.

5. The State of Maine has petitioned the federal Environmental Protection Agency to reduce sulfur dioxide emissions as certain plants in mid-western states that have high sulfur dioxide emissions. While the basis of this petition is visibility, it relates to those emissions causing acid rain as well.

Finally, I must stress that Maine already substantially complies with the limits established by the bill for coal emissions (1.2 lbs. of sulfur per million BTU on a 30 day average) and is easily within reach of that limit for oil with a 1.33 lbs. maximum. As the attached chart will indicate, the weighted average (.741 lbs.) of Maine power boiler sulfur emissions is well below the limits suggested in the proposed legislation.

Even if Maine were not a state that is impacted on a daily basis by the products of inadequately controlled sulfur emissions, borne by winds from the West, I would argue that our sister states should be required to meet the reasonable and achievable standards in your bill just on the grounds of equity. Tall stacks may be an answer to some, but they are not a solution to the most basic problem - too much sulfur in the air. Downwind states should not be made to suffer the economic and environmental consequences of the failure of the federal government to adequately address this problem.

Again, I regret being unable to attend the hearing. If I can answer any questions, please let me know.

Sincerely,

JOSEPH E. BRENNAN
Governor

JEB/sc

Enc.

UTILITY	1980 CONSUMPTION (GALLONS)	AVE. % S	TOTAL SO_2 TONS/YR.	LBS. S / 10^6BTU X % OF TOTAL FUEL
Bangor Hydro-Electric	7,434,000	2.15	1,255	1.12 X 4.89 = .055
Maine Public Service	1,132,800	2.14	190	1.12 X 0.74 = .009
CMP Wyman	129,040,800	1.25	12,650	0.66 X 84.85 = .560
CMP Mason	14,475,594	2.35	2,670	1.23 X 9.52 = .117
TOTAL	152,083,194		16,765	0.741 $\frac{\text{lbs. S}}{10^6\text{BTU}}$

Maine Ave. S Emission
Rate Weighted According
% Fuel Consumption

State of Maine
OFFICE OF THE GOVERNOR
AUGUSTA, MAINE 04333

TESTIMONY OF GOVERNOR JOSEPH E. BRENNAN
TO THE U.S. SENATE COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS
AUGUSTA CIVIC CENTER
April 14, 1981

RELEASE TIME: 10 a.m.

Good morning, Senator Mitchell.

I appreciate this opportunity to share my views with the Committee on an environmental issue that has long been of concern to me, and which I know is of deep and increasing concern to the people of the state of Maine.

With me this morning are Commissioner Henry Warren of the Department of Environmental Protection and members of his staff. They can comment on technical issues related to the problem of acid rain if you have any questions. Also present this morning is the Attorney General of Maine, James Tierney. He has prepared a report which includes a legal analysis of the problem and some suggested statutory changes.

That report is appended to my testimony for your review.

The evidence that has been developed in Maine to date indicates that acid rain does indeed affect our environment and has the potential for causing significant harm.

A review of the Clean Air Act and recent administration of its provisions suggest that stronger congressional action is needed to deal with the problem of long-range transport of air pollution.

Unfortunately, Maine is at the end of the geographic exhaust pipe.

We stand to lose substantial environmental quality, and we can expect economic loss if we do not take action to deal with the sources of this problem to the west of us.

As long ago as August 30, 1979, I addressed a specific objection to EPA regarding the proposed relaxation of air emission standards for two Ohio utility plants.

In February, 1980, I testified before the House Committee on Interstate and Foreign Commerce to express my deep concern about airborne pollutants, including sulfates, ozone and acid rain.

I regret that in April, 1981, nothing has occurred to diminish my concerns about these problems.

As you know, Maine has high quality air, and our industrial community has committed itself to substantial expenditures to maintain and improve that high quality.

Despite their efforts, air pollution from beyond our borders -- pollution that in no way is caused by these Maine industries -- is taking its toll on our state's environment.

Because acid rain causes minerals to leach from soil and bedrock, we are finding that some of our lakes contain increasing deposits of heavy metals such as lead, cadmium, zinc and aluminum. These metals are toxic to brook trout in their early stages of development. Aluminum is of particular concern because it is easily loosened from the bottom sediment and circulated into the water itself.

We have all heard of the problem of lakes in the Adirondacks of New York State and the Scandinavian Lakes in Europe which can no longer support fish. Results of our research to date indicate that Maine could soon experience similar losses.

Maine freshwater fisheries attract fishermen and tourists. As an economic resource, freshwater fishing generates millions of dollars annually. Losses of freshwater fisheries could have a very serious effect on Maine fishermen and the sporting lodges which depend on healthy fisheries, as well as on the work of our Department of Inland Fisheries and Wildlife.

Research also suggests that when acid rain is absorbed into the soil, tree growth can be affected. This problem requires further study. But with fiber production as our major industry and wood serving as a readily available alternative to imported oil, we cannot risk the possibility of further reductions in tree growth to add to those created by the spruce budworm.

Coordination and research on the acid rain problem is critical because more work needs to be done to evaluate cause and effect relationships.

The Maine Department of Environmental Protection has been working with the University of Maine at Orono, and research is now being conducted at Orono in forestry, soils, and fisheries at a program cost of $1.2 million.

Maine has one of the highest rates of cancer in the United States. We also have a high rate of multiple sclerosis. Both diseases are associated with environmental factors. Air emissions and long-range transport of pollutants are among these factors. Reports that the chances of dying from air pollution in the North Central and Northeastern parts of the United States are twice as high as the rest of the country are very sobering indeed.

The Maine Legislature has given all but final approval to a bill submitted by my Administration to establish an environmental health unit in our Department of Human Services.

This legislation will enable us to better study human health hazards that are related to pollution, hazardous materials and other substances we have introduced into our air and water.

But, like the efforts made by industry to improve air quality, this important advance does not stop airborne pollution.

The state-by-state approach is not sufficient to solve it.

Tall stacks, for example, may solve local emission problems, but downwind states suffer because of air transport.

This issue is not adequately covered by the Clean Air Act, and we at the state level cannot deal effectively with damaging air pollution that crosses the border into our state.

The 1981 Congressional review of the Clean Air Act gives us an opportunity to focus on the issue and perhaps develop revisions accordingly.

Maine is cooperating with its sister states and is willing to cooperate with the Congress in this effort.

There are various short-term responses to acidifying lakes such as adding lime or developing acid-resistant fish. However, these treat symptoms, not sources.

Atmospheric pollution is insidious, silent and invisible. To the casual observer, it isn't happening. But its consequences have been well documented. Therefore, we can't afford to take a wait-and-see attitude, because it could be too late for some aspects of the environment.

The issue of acid rain is too complex to address with a quick fix.

I believe that scientific research will continue to point to compelling reasons for controlling these problems at their source.

Since the states which contain the sources are unlikely to act as rapidly or effectively as we in the downwind states will find acceptable, it is imperative the Congress and the Environmental Protection Agency step up efforts at the national level.

The Clean Air Act and its administration by EPA are clearly inadequate to accomplish this goal.

The ultimate measure of a suitable program to respond to the acid rain problem will be in the projection of how much sulfur dioxide emissions can be reduced and how soon those reductions can occur.

But because air pollution has no respect for state boundaries, it falls upon Congress to provide us with strong, effective protection.

As I mentioned, I have attached the Attorney General's report to my testimony. I am also providing staff analysis and comments on both air quality and water quality issues which you mav find helpful.

I appreciate this opportunity to address the Committee.

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STATE OF NEW YORK
DEPARTMENT OF LAW
TWO WORLD TRADE CENTER
NEW YORK, N.Y. 10047
TELEPHONE: 212-488-7561

ROBERT ABRAMS
Attorney General

Honorable Robert Stafford, Chairman
Committee on the Environment and
Public Works
United States Senate
4204 Dirksen Senate Office Building
Washington, D.C. 20510

Dear Senator Stafford:

The Eastern States Attorneys General have long been concerned with ameliorating interstate air pollution, which causes damage to the public health and environment of our states. To this end, several of us have initiated litigation pursuant to the interstate provisions of the Clean Air Act. Our experience has led us to the conclusion that the basic processes are sound, but they need clarification and a few adjustments to make them more flexible. We therefore submit this Report to you and request your consideration of its proposals. We will also be submitting the Report to the House of Representatives.

Thank you for the opportunity to make these suggestions.

Very truly yours,

JAMES E. TIERNEY - Maine

JOHN J. EASTON, Jr. - Vermont

GREGORY H. SMITH - New Hampshire

DENNIS J. ROBERTS, II - Rhode Island

Robert Abrams

ROBERT ABRAMS - New York

CARL R. AJELLO - Connecticut

JAMES R. ZAZZALI - New Jersey

FRANCIS X. BELLOTTI- Massachusetts

REPORT TO CONGRESS OF THE EASTERN STATES' ATTORNEYS GENERAL

PROPOSED AMENDMENTS TO THE CLEAN AIR ACT: INTERSTATE AIR POLLUTION

Section I: Summary of Proposal

Our experience with the Clean Air Act has taught us the necessity of strong federal regulation of air pollution. As air moves across the country, it takes certain kinds of pollutants with it. This pollution is a federal concern just as surely as the interstate commerce that causes it is a federal concern.

If states are obliged to carry the whole burden of enforcing pollution standards, without clear federal standards and a strong federal enforcement program to see that all states do regulate pollution, then those states which maintain high environmental standards will do so at the cost of local jobs and industry. Federal standard-setting and strong enforcement are essential to prevent the state which regulates the least from determining other states' environmental standards -- in other words, to prevent the minimum controls from becoming the maximum.

Failures to control emissions in the Midwest disproportionately affect Eastern states. In order to compensate, the downwind states have had to devise even stricter controls. Several of the Attorneys General of the Eastern States have tried to use the Clean Air Act's interstate pollution remedies, but to little avail. We have therefore prepared this Report to Congress. The Report is presented in three sections: (1) a summary description of the problem and the legislative proposals, (2) proposed statutory language to express the needed changes and (3) a section-by-section analysis of the proposed amendments.

In 1977 Congress directed EPA to implement the new interstate provisions of the Act, but EPA has not done so. Congress must restate these directions more clearly. The Eastern States Attorneys General support the bills which have recently been introduced by Senator Mitchell (S. 1706) and Senator Moynihan (S. 1709). We have written our own proposed amendments to complement those bills. In addition, we recognize that Senator Dodd's bill (S. 1718) is an excellent effort to address the Act's present fundamental deficiencies with respect to interstate air pollution. We hope this Report will contribute to the process of review of the Act and we welcome debate on its merits.

Description of the Problem

Several kinds of interstate litigation have taken place under the Act. For instance, in 1978, New Jersey led Maine, Vermont, Massachusetts, Rhode Island, Connecticut, New York State, New York City and the District of Columbia in challenging EPA's failure to require all states east of the Mississippi to make comparable efforts to identify and control emissions of ozone precursors.* However, the Eastern States Attorneys General have had the greatest amount of experience with one particularly pressing interstate pollution problem--sulfur dioxide (SO_2) and particulate emissions from power plants. This summary of our experience will therefore concentrate on the history of this litigation and the practical problems we have faced in the course of it.

Sulfates are fine particles which have been shown to have serious adverse effects on human health. They are also major contributors to acid deposition and precipitation and to poor visibility, which has both economic and social effects.** The Northeast has generally high ambient sulfate levels, but local emissions sources do not account for these levels.

We know that sulfates are in part formed in the atmosphere from sulfur dioxide (SO_2) emissions. The largest concentration of SO_2 emissions in the country is located in the Ohio River Basin, directly upwind from the eastern states in the area's predominant meteorological patterns. In 1978 the States of Illinois, Indiana, Michigan, Ohio, Tennessee, Kentucky and West Virginia emitted approximately

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*New Jersey, EPA, Civ. No. 78-1392, D.C. Circuit 1980.

**The annual economic cost of acid rain in the eastern third of the United States has been estimated at five billion dollars (1978). Statement by Thomas Crocker, Professor of Economics, University of Wyoming, Laramie, before the U.S. Senate Small Business Committee and the U.S. Senate Committee on Environment and Public Works, Sept. 23, 1980.

11.3 million tons SO_2 per year. In comparison, combined emissions from the states of New York, New Jersey and all New England states totaled only approximately 2 million tons per year.* Emissions from Ohio alone exceeded by 50% the combined total emissionsof New York, New Jersey and all New England states. Emissions from utility sources contribute a high percentage to the total national emissions for sulfur dioxide. Older power plants are of primary concern, because they may emit five to seven times the amount of sulfur dioxide permitted from new sources.**

Since 1980 Connecticut, New Jersey, Pennsylvania, New York and Maine have sought redress through the interstate provisions of the Clean Air Act.***

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*U.S.-Canada Memorandum of Intent, Emissions, Costs and Engineering Assessment Interim Report, February, 1981, p. 92.

**National Commission on Air Quality, To Breathe Clean Air, p. 3.9-12.

***In addition to these, there have been several other interstate air pollution cases. In January, 1979, both the State of Pennsylvania and Council of Senior West Virginians, Inc., challenged EPA's approval of a West Virginia SIP revision because it did not comply with § 110(a)(2)(E). West Virginia has also relied on § 126 of the Act to challenge the Ohio Edison Sammis power plant's emissions. Jefferson County, Kentucky, filed two § 126 petitions in May, 1979, concerning two sources of SO_2 nearby in Indiana; EPA failed to act on them until the petitioner went to federal court during the spring of 1981 to seek an order compelling EPA action. EPA has now formally proposed to dismiss one of the petitions. 46 Fed. Reg. 38937 (1981).

These states' petitions pointed out to EPA that §§ 110(a)(2)(E) and (a)(3) of the Act require EPA to make a determination that no interstate air pollution will be caused before EPA may approve a SIP or SIP revision.* Moreover, EPA has never conducted an over-all review of the SIPs for interstate effects, even though this was clearly contemplated by the 1977 Amendments to the Act. Nor has EPA required states to list potential major sources of interstate pollution as § 126(a) of the Act requires.** New York and Pennsylvania therefore requested EPA to identify and assess the cumulative effects of midwestern sulfur dioxide emissions.

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*In December of 1980 Pennsylvania and New York filed petitions with EPA, pursuant to § 126 of the Act. In January and March, 1981, New York filed further petitions and sought disapproval of pending increases in the emissions of 24 large power plants in six midwestern states. Connecticut and New Jersey filed § 126 petitions in 1980 concerning two power plants in New York; the petitions challenged the adequacy of New York's interstate impact determinations for its SIP revisions. In the midwestern SIP revision proceedings brought by New York and Pennsylvania, no such determination has even been attempted by the midwestern states.

**The petitions which New York filed with EPA have focused on certain midwestern power plants because they were subjects of SIP revision proceedings pursuant to § 110(a) of the Clean Air Act. SIP revisions are being proposed which would increase allowable SO_2 emissions from these plants. New York's 1981 Petitions and Comments noted that an increase of 1.5 million tons annually in allowable SO_2 emissions would result if EPA granted each of the emission limit relaxations requested by the midwestern states and utilities. Such action would have increased actual emissions by approximately 511,000 tons annually. "Report of the New York State Attorney General: Pending Increases in SO_2 Emissions From Selected Coal Fired Electric Plants in Midwest States." See also the Report of the National Commission on Air Quality, To Breathe Clean Air, at p. 3.9-25.

In spite of these petitions, EPA has continued to approve a number of the SIP revisions which allow increased SO_2 emissions.* EPA has not assessed the interstate impacts of these revisions. The states are seeking review of EPA's actions in the federal courts.

In the meantime, EPA has instituted a proceeding, pursuant to § 126(b) of the Act, to review New York's and Pennsylvania's petitions. However, EPA has defined the scope of this proceeding to preclude consideration of the cumulative impacts of the emissions allowed by the midwestern SIPs. EPA also refuses to consider sulfate effects and acid deposition and precipitation. Finally, EPA has issued "criteria" for § 126 petitions, in which it attempts to shift the burden of proof of interstate impacts away from itself and onto the petitioning states. Sections 110(a)(2)(E) and 307(d) of the Act clearly preclude this approach. A hearing was held in June of this year. New York, Pennsylvania, Connecticut, Massachusetts, the Canadian

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*EPA has approved emission limit increases at some plants (the Cardinal, Bayshore and Cobb plants) and has proposed to increase allowable emissions at others (Niles and Miami Fort plants). Furthermore, EPA has granted long delays in the compliance deadlines for several plants; these are the Cardinal, Conesville, and Muskingum Plants. 45 Fed. Reg. 73927 (1980). EPA has also suspended the more restrictive limits which were due to come into effect for two of the Cleveland Electric Illuminating plants, Avon Lake and East Lake. 45 Fed. Reg. 42279 (1981).

Provinces of Ontario and Quebec and many other interested parties have submitted extensive testimony. In October, 1981, Maine filed a § 126 petition and evidence in this proceeding highlighting the damage to visibility in Maine due to transported sulfates.

The evidence in the EPA record demonstrates long-range transport of damaging pollutants into the Northeast. It has been corroborated by several witnesses in the recent testimony given before Congress. For example, Dr. Robert Friedman, of the Congressional Office of Technology Assessment, testified before the Senate Committee this summer that 70% of New York State's ambient sulfate pollution originates outside of New York. The record in the New York-Pennsylvania § 126 proceeding indicates even higher percentages and supports the findings of the National Commission on Air Quality (NCAQ) and the National Research Council of the National Academy of Sciences: that sulfates are transported from the Midwest to the Northeast in large and damaging amounts.* No testimony presented at the [illegible] hearings contradicted this conclusion. Only the ability to quantify the contribution of midwestern sources to eastern pollution was questioned by some at the proceeding.

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*NCAQ, To Breathe Clean Air, 1981, p. 3.9-1. National Research Council, Atmosphere-Biosphere Interactions: Toward a Better Understanding of the Ecological Consequences of Fossil Fuel Combustion, National Academy of Sciences, Natural Academy Press, 1981.

Overview of the Attorney Generals' Proposals

This litigation experience has led us to formulate our own proposals for amendments to the Act. A clearer mandate to EPA from Congress and a specific requirement of equity among the states are needed in the Act. The interstate equity which Congress wrote into the 1977 Amendments must be maintained and strengthened. If there is one area in which the federal role as leader and umpire cannot be abandoned, it is in interstate air pollution.

In addition, a petitioning state should not bear the burden of proof in a proceeding under § 126. Rather, EPA should bear it, as the Act now provides. Keeping the present balance of responsibility is essential: it is EPA that has the greater information and research resources, and it is EPA that is responsible for setting interstate standards and reviewing approving SIPs to make sure they do not interfere with other states.

Although the Act now contains a basic structure to deal with interstate problems, these processes have not been used effectively. The Act's processes should be retained essentially as they are, but with a few changes. In addition, those serious pollution problems which have gone unchecked during the past -- particularly sulfates and ozone -- should be the subject of direct legislative mandates to control emissions, such as are contained in S. 1706 and S. 1709.

Three segments of the Act relate to control of interstate pollution. These should be made more explicit:

1. Section 110(a)(2)(E). The states and EPA must each have an absolutely clear responsibility to prevent interstate pollution, through careful SIP preparation and review. The present language of § 110(a)(2)(E) has been construed by EPA so as to deprive it of any meaning. A few phrasing adjustments would make it clearer that the section requires states to set their sources' emission limits at levels which will not burden downwind states and that EPA may not approve a SIP which will cause inequities among the states.

2. National Ambient Air Quality Standards. It should be clearer that it is EPA's responsibility to establish pollution standards which incorporate interstate considerations, including meteorological transport patterns, chemical transformations in the atmosphere and synergism, and also to consider the impacts of different deposition mechanisms, such as rain. Standards should be established for pollutants which not may not cause serious local problems but do inflict damage at a distance from the source. Section 109 should provide a specific authority to EPA to regulate pollution on a regional and non-ambient basis.

3. Section 126. Congress should revise § 126 in two respects. First, any pollutant should be a

permissible subject of a state's § 126(b) petition. In the current EPA § 126 hearing, EPA has refused to consider evidence on sulfate impacts on the Northeast, even though it is clear that transported sulfates are damaging the region. EPA claims it has no authority to consider sulfates because it has set no NAAQS for them. 46 Fed. Reg. 24602 (1981).

Because of chemical transformations in the atmosphere, damaging impacts may be caused by a pollutant which is a different chemical or compound from the one originally emitted. This is the case with ozone and with acid rain. By limiting interstate petitions to pollutants which EPA is already regulating, the Act tends to preclude consideration of unique secondary impacts.

Each state must have the right to petition for a finding of adverse impact from any out-of-state pollution. The states have substantial technical expertise in the fields of meteorology, atmospheric chemistry and the health sciences and they are prepared to present their case on sulfate pollution in a federal forum. While Section 115 of the Act, International Air Pollution, has no restriction on what pollutants may be the subject of its processes, the § 126 forum is more limited. The Act provides the states with less opportunity to seek relief than it provides to foreign countries. Section 126 should be an open door which would direct EPA to grant relief to states from any significant interstate pollution problem.

Second, Section 126 should explicitly require EPA to set standards to abate interstate pollution, even when EPA cannot quantify exact source-receptor ties. When large numbers of sources emit pollutants which are gathered into the atmosphere and transported to distant areas, the cumulative impact may be very harmful, even though the original emissions were small and caused no harm locally. EPA should be required to abate any identified interstate pollution problem by setting a technology-based emission standard or a total air mass loading limit, established on a basis of equity among the states.

In addition to these amendments to the present Act, we urge that Congress enact a direct requirement of substantial reductions of sulfur pollutants emitted by midwestern power plants. Recently Senator Mitchell of Maine and Senator Moynihan of New York proposed measures which would roll back SO_2 emissions nationally. We fully support these bills (S. 1706 and S. 1709).

Congress should also direct EPA to control such related pollutants as hydrocarbons and to strictly maintain automobile controls. Ozone precursors cause interstate problems all over the country and increasingly severe damage is resulting, particularly in the Eastern states.

The states need strong, clear, specific federal laws to address interstate problems such as the long-range transport of air pollutants. These problems cannot be addressed on the local and state levels alone. They must be handled in a national framework. It is the task of Congress to give coherent directions to the EPA to face these difficulties and resolve them to the best of its ability.

SECTION II:

Proposed Statutory Language

The following section sets out the specific changes in the language of the Clean Air Act which the Eastern States Attorneys General propose. Present language which should be deleted is crossed out. Additions are underlined.

Section 107 - Air Quality Control Regions

(a) Each State shall have the primary responsibility for assuring air quality within the entire geographic area comprising such State and for assuring compliance with interstate air quality controls applicable to emissions sources within such State by submitting an implementation plan for such State which will specify the manner in which national primary and secondary ambient air quality standards will be achieved and maintained within each air quality control region in such State.

* * *

(c)(1) The Administrator shall, ~~within 90 days after December 31, 1970,~~ after consultation with appropriate State and local authorities, designate as an air quality control region any interstate area or major intrastate area which he deems necessary or appropriate for the attainment and maintenance of ambient air quality standards or implementation of interstate air quality control requirements. The administrator shall immediately notify the Governors of the affected States of any designation made under this subsection.

(2) Within 180 days after [date of reauthorization] the Administrator shall designate interstate air quality control regions appropriate for implementation of Part E of this Subchapter (for control sulfur dioxide and other precursors of acid deposition) and for implementation of the interstate air quality control requirements for ozone and ozone precursors required to be issued pursuant to section 109(e). These regions shall be sufficiently large so as to include all appropriate sources and receptors. One such region for control of ozone shall include at a minimum all of the states east of the Mississippi River.

(d)(1) For the purpose of transportation control planning and interstate control requirements, part D of this subchapter (relating to nonattainment), part C of this subchapter (relating to prevention of significant deterioration of air quality) and Part E (relating to control of sulfur dioxide and particulates), and for other purposes, each State~~, within one hundred and twenty days after August 7, 1977~~, shall submit to the Administrator a list, together with a summary of the available information, identifying those air quality control regions, or portions thereof, established pursuant to this section in such State which on August 7, 1977:

> (A) do not meet a national primary ambient air quality standard for any air pollutant other than sulfur dioxide or particulate matter;
>
> (B) do not meet, or in the judgment of the State may not in the time period required by an applicable implementation plan attain or maintain, any national primary ambient air quality standard for sulfur dioxide or particulate matter;
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> (C) do not meet a national secondary ambient air quality standard;
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> (D) cannot be classified under subparagraph (B) or (C) of this paragraph on the basis of available information, for ambient air quality levels for sulfur oxides or particulate matter; or
>
> (E) have ambient air quality levels better than any national primary or secondary air quality standard other than for sulfur dioxide or particulate matter, or for which there is not sufficient data to be classified under subparagraph (A) or (C) of this paragraph.

* * *

(6) As of two years after [date of reauthorization] any region or portion thereof still unclassified under subparagraphs (d) or (E) of paragraph (1) of this subsection shall thereafter be deemed to be in nonattainment until reclassified pursuant to subsection (e) of this section.

Section 108 - Air Quality Criteria and Control Techniques

(a)(1) For the purpose of establishing national primary and secondary ambient air quality standards or interstate air pollution control requirements, the Administrator shall ~~within 30 days after December 31, 1970,~~ publish, and shall from time to time thereafter revise, a list which includes each air pollutant:

(A) emissions of which, in his judgment, cause or contribute to air pollution which may reasonably anticipated to endanger public health or welfare;

(B) the presence of which in the ambient air results from numerous or diverse mobile or statutory sources~~; and~~.

~~(C) for which air quality criteria had not been issued before December 31, 1970, but for which he plans to issue air quality criteria under this section.~~

(2) The Administrator shall issue air quality criteria for an air pollutant within 12 months after he has included such pollutant in a list under paragraph (1). Air quality criteria for an air pollutant shall accurately reflect all of the latest scientific knowledge and research indicating the kind and extent of all identifiable effects on public health or welfare which may be expected from the presence of such pollutant in the ambient air, in varying quantities. The criteria for an air pollutant, to the extent practicable, shall include information on:

(A) those variable factors (including local and interstate atmospheric conditions and other geographic variables) which of themselves or in combination with other factors may alter the effects on public health or welfare of such air pollutant;

(B) the types of air pollutants which, when present in the atmosphere, may interact with such pollutant to produce an adverse effect on public health or welfare; and

(C) any known or anticipated adverse effects on welfare.

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* * *

(d) Not later than six months after date of reauthorization, the Administrator shall issue criteria relating to concentration of fine particles over an appropriate time period. Such criteria shall include at least a discussion of chemical subspecies, including sulfates and nitrates and diesel combustion emission.

[The present subsection (d) becomes (e)]

[The present subsection (e) becomes (f)]

~~(f)~~ (g) (1) The Administrator shall publish and make available to appropriate Federal agencies, States, and air pollution control agencies, including agencies assisted under section 7505 of this title within 6 months after ~~August 7, 1977~~ [date of reauthorization] for clauses (i), (ii), (iii), and (iv) of subparagraph (A) and within one year after August 7, 1977, for the balance of this subsection (and from time to time thereafter),

(A) information, prepared, as appropriate, in cooperation with the Secretary of Transportation, regarding processes, procedures, and methods to reduce or control each such pollutant, including but not limited to:

(i) motor vehicle emission inspection and maintenance programs; [etc.]

* * *

(B) information on additional methods of strategies that will contribute to the reduction of mobile source related pollutants during periods in which any primary ambient air quality standard will be exceeded and during episodes for which an air pollution alert, warning, or emergency has been declared;

(C) information on other measures which may be employed to reduce the impact on public health or protect the health of sensitive or susceptible individuals or groups; and

(D) information on the extent to which any process, procedure, or method to reduce or control such air pollutant may cause an increase in the emission or formation of any other pollutant;

(E) information prepared in cooperation with the Secretary of Energy (or any appropriate successor agency) regarding

(i) processes, procedures and methods to conserve energy and

(ii) the development and use of fuel combustion energy generation processes with the least air pollution emissions.

Section 109 - National primary and secondary ambient air quality standards and interstate air pollution control requirements.

(a)(1) The Administrator:

(A) within 30 days after December 31, 1970, shall publish proposed regulations prescribing a national primary ambient air quality standard and a national secondary ambient air quality standard for each air pollutant for which air quality criteria have been issued prior to such date; and

(B) after a reasonable time for interested persons to submit written comments thereon (but no later than 90 days after the initial publication of such proposed standards shall be regulation promulgate such proposed national primary and secondary ambient air quality standards with such modifications as he deems appropriate.

(2) With respect to any air pollutant for which air quality criteria are issued after December 31, 1970, the Administrator shall publish, simultaneously with the issuance of such criteria and information, proposed national primary and secondary ambient air quality standards for any such pollutant. The procedure provided for in paragraph (1)(B) of this subsection shall apply to the promulgation of such standards.

(b)(1) National primary ambient air quality standards, prescribed under subsection (a) of this section shall be ambient air quality standards the attainment and maintenance of which in the judgment of the Administrator, based on such criteria and allowing an adequate margin of safety, are requisite to protect the public health. Such primary standards may be revised in the same manner as promulgated.

(2) Any national secondary ambient air quality standard prescribed under subsection (a) of this section shall specify a level of air quality the attainment and maintenance of which in the judgment of the Administrator, based on such criteria, is requisite to protect the public welfare from any known or anticipated adverse effects associated with the presence of such air pollutant in the ambient air. Such adverse effects shall include but not be limited to, cumulative and episodic effects, the effects of polluted precipitation, the effects of secondary pollutants and effects on visibility. Such secondary standards may be revised in the same manner as promulgated.

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(d) The Administrator shall, not later than one year after [date of reauthorization] promulgate a national primary ambient air quality standard for fine particulates unless, based on the criteria issued under section § 108(d) of this title, he finds that there is no significant evidence that such a standard would protect public health and welfare.

(e) The Administrator shall publish regulations prescribing interstate air quality controls for control of the adverse effects of air pollutant impacts which have been identified pursuant to § 108, but for which national ambient standards are not appropriate because the impacts are not national in scope, because ambient measurements are not an appropriate measure of the pollution impacts or because other factors dictate an alternative approach to regulation. Such air quality controls may include (i) specific emissions limits for sources or categories of sources, (ii) state or area pollution loading limits, or (iii) technology or process requirements. Interstate air quality control requirements promulgated pursuant to this subsection shall insure equitable distribution of emission controls among the states in the AQCR. Any agreement among states to reduce pollutant emissions may be incorporated in the proposed interstate air quality control requirements, provided that the overall effect of the agreement is consistent with applicable interstate air pollution control requirements. Such agreements shall be federally enforceable.

(f) Within 180 days of designation of the interstate air quality control regions required by § 107(c)(2), the Administrator shall propose interstate air quality control requirements pursuant to Part E of this subchapter. Within 180 days after issuance of these proposals, the Administrator shall promulgate final regulations imposing such controls.

(g) Within 180 days of [date of reauthorization] the Administrator shall promulgate regulations imposing Reasonably Available Control Technology (RACT) requirements on all stationary sources of Volatile Organic Compounds (VOCs) emitting more than 100 tons per year in the interstate pollution AQCR for ozone, established pursuant to section 107(c)(2), to reduce actual emissions in attainment and unclassified areas. In addition, within 180 days of [date of reauthorization] the Administrator shall issue proposed regulations defining RACT for VOCs for chemical manufacturing industrial processes. Final regulations shall be promulgated within 120 days of issuance of proposed regulations.

[The present subsection (d) becomes (h).]

Section 110(a)(2)(E) - Interstate Pollution SIP Requirements

(2) The Administrator shall, within four months after the date required for submission of a plan under paragraph (1), approve or disapprove such plan or each portion thereof, if he determines that it was adopted after reasonable notice and hearing and that:

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(E) it contains adequate provisions (i) prohibiting any stationary source or group of sources within the State from emitting any air pollutant in amounts which will (I) ~~prevent~~ interfere with attainment or maintenance by any other State of any such national primary or secondary ambient air quality standard, or (II) interfere with measures required to be included in the applicable implementation plan for any other State under part C of this subchapter to prevent significant deterioration of air quality or to protect visibility, and (ii) ~~insuring compliance with the requirements of section 7426 of this title, relating to interstate air pollution abatement;~~ to insure compliance with interstate air pollution control requirements established pursuant to sections 109 or 126;

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Section 123 - Stack heights

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(c) Not later than six months after ~~August 7, 1977,~~ [date of reauthorization] the Administrator, shall after notice and opportunity for public hearing, promulgate regulations to carry out this section. For purposes of this section, good engineering practice means, with respect to stack heights, the height necessary to insure that emissions from the stack do not result in excessive concentrations of any air pollutant in the immediate ~~vicinity~~ impact area of the source as a result of atmospheric downwash, eddies and wakes which may be created by the source itself, nearby structures or nearby terrain obstacles (as determined by the Administrator). ~~For purposes of this section such height shall not exceed two and a half times the height of such source unless the owner or operator of the source demonstrates, after notice and opportunity for public hearing, to the satisfaction of the Administrator, that a greater height is necessary as provided under the preceding sentence. In no event may the~~ The Administrator may prohibit any increase in any stack height or restrict in any manner the stack height of any source.

(d) The Administrator shall by January 20, 1983, complete a review of the emission limits for all existing major sources which have come into existence since 1970 or which have raised the stack height in the plant since 1970, in order to determine whether emission limits for such sources are inappropriately based upon model credit for stack height above good engineering practice. If emission limits are determined to be inappropriately based, the Administrator shall require the state to submit a revision to the State Implementation Plan within six months to correct the emission limit to conform with requirements of this section. It shall be the burden of the operator of each such source to demonstrate the correct stack height credit to be used in determining proper emission limits.

Section 126 - Interstate Pollution Abatement

~~(a) Each applicable implementation plan shall--~~

~~(1) require each major proposed new (or modified) source--~~

~~(A) subject to part C of this subchapter (relating to significant deterioration of air quality) or~~

~~(B) which may significantly contribute to levels of air pollution in excess of the national ambient air quality standards in any air quality control region outside the State in which such source intends to locate (or make such modification),~~

~~to provide written notice to all nearby States the air pollution levels of which may be affected by such source at least sixty days prior to the date on which commencement of construction is to be permitted by the State providing notice, and~~

~~(2) identify all major existing stationary sources which may have the impact described in paragraph (1) with respect to new or modified sources and provide notice to all nearby States of the identity of such sources not later than three months after August 7, 1977.~~

(a) Within 90 days of publication of interstate control requirements pursuant to this section or section 109, each state in which there are sources subject to these controls shall submit to the Administrator a list of each source in the state which is subject to the interstate control requirements.

(b) Any State or political subdivision may petition the Administrator for a finding that any major source or group of sources emits or would emit any air pollutant in violation of the prohibition of section 7410(a)(2)(E)~~(i)~~ of this title or is causing or contributing to air pollution which endangers the public health or welfare of the petitioning state. Within 60 days after receipt of any petition under this subsection ~~and after public hearing~~ the Administrator shall hold a public hearing. The Administrator shall make ~~such~~ a finding or deny the petition, pursuant to section 307(d), within 120 days of this hearing.

(c) Upon making an affirmative finding pursuant to subsection (b) of this section, the Administrator shall within 180 days

(1) establish an interstate air quality control region pursuant to section 107 encompassing the source and receptor areas if no such region has already been established;

(2) determine whether specific sources may be identified, emitting such pollutants or precursors of such pollutants,

(A) if so, establish emission limits or other controls on the identified sources or

(B) if not, establish an equitable emission reduction strategy applicable to an appropriate category or categories of sources.

Such limits, controls or other emission reduction strategy shall be sufficient to abate the condition found by the Administrator pursuant to subsection (b).

~~(c)~~ (d) Notwithstanding any permit which may have been granted by the State in which the source is located (or intends to locate), it shall be a violation of the applicable implementation plan in such State:

(1) for any major ~~proposed new~~ modification of a source with respect to which a finding has been made under subsection (b) or (c) of this section to be constructed or for any source to operate in violation of limits promulgated pursuant to subsection (c) of this section or section 109(d) or (e) or

(2) for any ~~major existing~~ source to operate more than three months after such finding has been made with respect to it. The Administrator may permit the continued operation of a source referred to in paragraph (2) beyond the expiration of such three-month period if such source complies with such emission limitations and compliance schedules (containing increments of progress) as may be provided by the Administrator to bring about compliance with the requirements contained in section 7410(a)(2)(E)(i) of this title as expeditiously as practicable, but in no case later than three years after the date of such finding. Nothing in the preceding sentence shall be construed to preclude any such source from being eligible for an enforcement order under section 7413(d) of this title after the expiration of such period during which the Administrator has permitted continuous operation.

(e) The Administrator shall not aprove that part of a SIP or SIP revision which is the subject pending petition filed pursuant to subsection (b) of this section.

Section 304 - Citizens Suits

* * *

(e) Nothing in this section shall restrict any right which any person (or class of persons) may have under any statute or state or federal common law to seek enforcement of any emission standard or limitation or to seek any other relief (including relief against the Administrator or a State agency). ...

* * *

Section 307

(b)(1) [Judicial review of] . . . any other final action of the Administrator under this chapter (including any denial or disapproval by the Administrator under this subchapter I of this chapter) which is locally ~~or regionally~~ applicable may be filed only in the United States Court of Appeals for the appropriate circuit. Notwithstanding the preceding sentence a petition for review of any action referred to in such sentence may be filed only in the United States Court of Appeals for the District of Columbia if such action is based on a determination of nationwide scope or effect ~~and~~ or if in taking such action the Administrator finds and publishes that such action is based on such a determination.

PART E

A new Part E is recommended to explicitly require specific reductions in SO_2 emissions and other. The Eastern States' Attorneys' General support the bills proposed by Senators Mitchell and Senator Moynihan, which would provide for such requirements in a new Part E. These are Senate Bills Nos. 1706 and 1709 respectively. In addition, we recommend the inclusion of the following provision:

Reduction of SO_2 emissions:

* * * * *

(1) All solid fossil fuel combusted in the interstate air quality control region designated pursuant to § 107(c)(2) shall be cleaned to reduce sulfur content prior to combustion. The Administrator, nor later than December 31, 1982, shall publish regulations establishing standards of performance for fuel cleaning facilities which reflects the degree of sulfur reduction achievable through the application of the best technological system which the Administrator determines has been adequately demonstrated, taking into account natural sulfur content and heat loss not exceeding 20%. The regulations may exempt from this requirement:

(a) all solid fossil fuels which, when combusted, emit sulfur at a rate equal to, or less than, 1.5 lb/MMbtu; or

(b) all solid fossil fuels combused at sources which comply with applicable standards of performance for new sources under Section 111.

Each stationary source which combusts solid fossil fuels in an amount greater than one million tons per year shall submit, by not later than March 31, 1983, a plan to comply with this subsection, which shall specify a schedule for compliance as expeditiously as practical, but not to extend beyond December 31, 1984. The Administrator shall approve each plan which meets the requirements of this subsection by order issued pursuant to Section 113.

SECTION III:

Section-By-Section Analysis

The following section discusses the rationale for each of the amendments proposed in Section II of this Report.

Section 107 - Air Quality Regions

Section 107 both establishes the states' responsibility to maintain air quality within their borders and authorizes the EPA Administrator to define geographic areas for implementation of standards. Three amendments to it are proposed:

(1) The states' responsibility to comply with interstate requirements should be specified in § 107(a), just as their responsiblity to assure air quality within their own borders is expressly stated.

(2) Language is proposed for a new § 107(c)(2) to make it clear that the Administrator has the authority to establish an air quality control region (AQCR) to facilitate control of regional interstate pollution problems. The EPA would first identify the region which encompasses both sources and receptors of the pollution. After definition of the affected area as an interstate AQCR, emission limits by category of source or total state loading limits would be established pursuant to § 109 or § 126 (see below) for all states in the Regional AQCR. The interstate AQCR is analogous to the air pollution transport corridor, which the National Governors' Association has recommended.

(3) There should be a statutory time limit on state designations of ACQRs as "nonclassifiable on the basis of available information." There are now a number of states

which have failed to thoroughly monitor air quality; unmonitored areas are treated as attainment areas. This is so, even though many actually may be nonattainment areas and are contributing significantly to interstate air pollution, particularly ozone. A time limit on designation is therefore proposed in a new subsection 107(d)(6) and any area not designated will be treated as a nonattainment area.

Section 108 - Air Quality Criteria and Control Techniques

This section describes the scientific bases for ambient standards and establishes the standard development process. Four changes are proposed:

(1) Section 108(a)(1)(c) should be deleted. It serves no substantive function in the NAAQS process. If a pollutant meets the substantive tests of § 108(a)(1)(A) and (B), the Act clearly contemplates that it will be designated as a pollutant. That is, if it is present in the ambient air, results from numerous or diverse sources and causes or contributes to pollution which may reasonably be anticipated to endanger public health or welfare, it should be listed and regulated. If Congress intends that the Administrator not be required to regulate pollutants which meet the NAAQS substantive requirements, then any appropriate basis for not regulating should be clearly stated in the Act.

(2) The factors which the criteria documents must consider are already broad and a plain reading of them

includes regional/interstate aspects. However, given EPA's narrow interpretations of the Act in the past, § 108(a)(2) should be clarified to make explicit the requirement that transport factors and all relevant evidence of transport be considered.

(3) A new section 108(d) should be inserted to direct EPA to establish NAAQS for fine particulates, as it was directed to do for NO_2 in 1977. Under present standards, fine particles are virtually unregulated, even though it is generally recognized that they pose significant health risks. The current standard allows accumulation of very high concentrations of fine particles within EPA's established limits.*

(4) Section 108(f) should be revised to direct EPA to work with the Department of Energy or the appropriate successor agency, to develop energy conservation strategies and encourage use of low pollution energy sources.

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*The Total Suspended Particulate (TSP) NAAQS standards now in effect limit particulate emissions by weight. They are insensitive to fine particulates. A particle with a diameter of 0.1 micron has a mass equal to 1 millionth the mass of a 10 micron diameter particle. Thus, small particles may represent 90% of the total number of particles and yet comprise a trivial fraction of the TSP mass. Perera, F.P. and A.K. Ahmed, Respirable Particles; Impact of Airborne Fine Particulates on Health and the Environment, Ballinger Publ. Co., Cambridge, Mass. 1979; Wilson, R. et al., Health Effects of Fossil Fuel Burning. Ballinger Publ. Co. Cambridge, Mass., 1980; Lippman, M. et al., "Effects of sulfuric acid aerosols on respiratory tract airways." Paper presented at the Fifth British Occupational Hygiene Society International Symposium on Inhaled Particles, Cardiff, Wales, Sept. 1980; Wolff, G.T. et al. "Characterization of Aerosols Upwind of New York City: I. Transport," Ann. N.Y. Acad. Sci. 322:57-72, 1979.

§ 109 - National Ambient Qir Quality Standards and Interstate Air Pollution Control Requirements

This section directs the Administrator of EPA to establish national primary and secondary ambient air quality standards and to update them periodically as new scientific information becomes available. EPA has tended to interpret this authority very narrowly, in spite of the broad language of the Act. The following changes are therefore proposed:

(1) An additional sentence is included in subsection (b)(2) to elaborate on the kinds of adverse effects which are to be prevented by the secondary standards. Consideration of these effects is implicitly required by the present language, but it should be explicit.

(2) Explicit authority to set interstate air quality control requirements on a non-ambient basis is proposed. For example, such requirements might be emission limits for sources or categories of sources or categories of sources in a particular region; they could also be state or area loading limits or any other appropriate control strategy. The interstate control requirements would be implemented by the states through the SIP process and states would be authorized to use offsets to accomplish equivalent results.

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*Air Quality Criteria for Particulae Matter, U.S. Dept. of Health, Education and Welfare, Wash., D.C., 1969.

In addition, explicit limits for SO_2 emissions for sulfates and for ozone precursors should be mandated. A new Part E mandating SO_2 emission reductions should be enacted. Two such proposals are contained in Senate bills submitted by Senators Mitchell and Moynihan and sponsored by numerous other Senators. These bills are extremely important.

Section 110 - State Implementation Plans

This section contains the basic requirements for SIPs, and their review by EPA.

(1) Section 110(a)(2)(E) must clearly require states to consider interstate effects when setting emission limits contained in the SIPs. These emission limits must be set at a level which will prevent the interstate effects prohibited by § 110(a)(2)(E).

(2) The use of the word "prevent" (attainment and maintenance) in this section has been construed to mean that the provision is violated only if out-of-state pollution by itself causes an exceedance of a standard. This literal reading leads to the result that a downwind state would have to reduce its emissions far enough below the standard to accommodate all out-of-state pollution. Obviously this is not the result Congress intended.

Under the Act as it now reads, both attainment and maintenance are to be protected. However, using only the word "interfere" would indicate more clearly that an equitable balance between the states should be achieved. In addition, a basic standard of equity should be explicitly stated in this section. It should also be clearer that SIPs cannot be approved if they do not conform to relevant orders issued by the Administrator pursuant to § 126.

Section 123 - Stack Heights

Section 123 has not had the intended effect of discouraging stack height increases. On the contrary, since 1970 one hundred and sixty seven stacks taller than 500 feet have been built by utilities in the U.S.*

EPA has never promulgated final regulations to carry out the intent of § 123. Furthermore, EPA has taken the position in litigation that sources which raised their stack heights and achieved an emission limit relaxation thereby, are exempt from the requirements of § 123 if the SIP revision was completed prior to EPA action in promulgating regulations under that section. See, Pennsylvania v. EPA, US Ct. of Appeals, 3rd Cir., EPA Brief at page 36-37. Also, EPA's present proposed interpretation of § 123 is contrary to the language of the statute and the Congressional history of the section. See, 45 Federal Register 42279, 42281; H.R. Rep. No. 95-294, 95th Cong., 1st Session 83-86 (1977), 12 U.S. Code Cong. and Admin. News (1977).

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*EPA, 1979, Identifying and Assessing Technical Bases for Stack Height for EPA Regulatory Process, Preliminary Report No. 69-02-3323.

Three changes are proposed for section 123:

(1) The automatic rule of thumb -- 21/2 times the height of the plant -- is deleted and application of good engineering practice is required on a case-by-case basis.

(2) The Administrator is authorized to prohibit increases in stack height.

(3) A new subsection (d) is added requiring EPA to review the emissions limits of all major sources which have increased their stack height since 1970 and to disallow any modelling credit for stack heights which do not conform to good engineering practice.

Section 126 - Interstate Pollution Abatement

Several changes are proposed:

(1) Section 126(a) should be revised to establish an inventory and reporting requirement. States would report to EPA all sources subject to interstate controls. This would be a more modest task, more realistic to expect of states and more useful in enforcement of interstate controls than the present § 126(a) requires.

(2) In addition, we propose to enlarge the basis on which a 126(b) petition may be brought to include any significant endangerment to the public health or welfare of the petitioning state's citizens. Because of chemical transformations in the atmosphere, damaging impacts may be caused by a pollutant which is a different chemical or compound from the one originally emitted. This is the case with ozone and with acid rain. Limiting interstate petitions to pollutants for which EPA has already established a NAAQS precludes consideration of regional secondary impacts.

Each state should be able to petition for a finding of adverse impact from any out-of-state pollution. The § 126 forum is currently more limited than section 115 of the Act, International Air Pollution, which has no restriction on what pollutants may be the subject or its processes. Section 126 should be an open door which would direct EPA to grant relief to states from any significant interstate pollution problem.

(3) A new subsection (c) is proposed. It would direct the Administrator to establish equitable emission limits to abate identified interstate pollution, even when the actual contribution of individual sources to the pollution cannot be quantified. The cumulative impact of large numbers of sources may be very harmful at great distances downwind, even though the original emissions were small and caused no harm locally. EPA should be required to abate any identified interstate pollution problem by setting a technology-based emission standard or a total air mass loading limit, established on a basis of equity among the states.

(4) The present subsection (c) becomes subsection (d) and is modified to coordinate with the changes on the section.

Proposed Revisions Concerning Judicial Review

(1) Section 304(e). It should be made more clear that the Act is not intended to restrict any existing law right, either state or federal. In its recent reversal of the Seventh Circuit's decision upholding Illinois' federal common law nuisance claim, in Illinois v. Milwaukee, ____ U.S. ____ (1981), the Supreme Court relied heavily on the fact that the Federal Water Pollution Control Amendments' saving clause did not explicitly reserve federal common law rights. It should be clearly stated in the Clean Air Act that federal and state common law rights are reserved.

(2) Section 307(b)(1). The legislative history of the 1977 Amendments supports review by the D.C. Circuit of any EPA actions which are nationwide in scope or effect, even if EPA has not explicitly designated the action as nationwide. This point of law becomes particularly important when a regional or transregional issue, such as acid deposition, is affected by SIP revisions. EPA has acknowledged that in this situation there is no one state which is the proper site for review. See EPA Brief in Commonwealth of Pennsylvania v. U.S.E.P.A., Third Circuit, Civ. No. 79-1026. The language revision proposed here would indicate that such an EPA designation is not necessary for the D.C. Circuit to take jurisdiction where a national or non-local case is presented.

Mandatory Coal Cleaning

This provision is suggested as an addition to the requirements put forward by Senate bills S. 1706 and S. 1709, and not as a self-sufficient provision. It would require all coal combusted in SO_2 interstate air quality control regions to be cleaned, as one method to achieve part of the required reduction of SO_2 specified in a new Part E. The language specifies that all coal is to be washed, except for (a) low sulfur coal with an emission potential of 1.5 lbs./MMbtu or less; or (b) coal used in NSPS plants, which must meet an emission rate of 1.2 lbs./MMbtu or less. It also requires EPA to set coal cleaning standards, reflecting the best available technology and directs major power plants to submit to EPA a plan for compliance by December 31, 1984. Compliance can be achieved by the purchase of cleaned coal or by construction of coal cleaning plants. All units which consume more than one million tons of coal per year (about 500 megawatts) are covered.

This provision is consistent with the coal cleaning proposal advocated by the Coalition of Northeastern Governors (CONEG).

BEFORE THE
ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C.

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In the Matter of Interstate : Docket No.
Air Pollution : A-81-09

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EVIDENCE SUMMARY: SULFATES TRANSPORTED INTO NEW YORK STATE-- IMPACTS AND ORIGINS

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October 7, 1981

I. NEW YORK STATE SUFFERS SERIOUS ADVERSE EFFECTS FROM SULFATE POLLUTION

Fine sulfate particles derived from SO_2 have been shown to comprise very high proportions of the measured ambient Total Suspended Particulate (TSP) levels in New York State. Compelling evidence, developed by EPA and by New York, indicates that sulfates and other fine particulate matter from midwestern SO_2 sources contribute heavily to pollution levels in New York. They cause New York to be unable to meet the TSP National Ambient Air Quality Standard (NAAQS) and interfere with New York's program of planning for Prevention of Significant Deterioration (PSD). Nevertheless, there has been no attempt by EPA to assess the impacts of these sulfur dioxide increases on TSP levels at short or long distances from the coal fired power plants involved in this proceeding.

This document will explain the harmful effects of these sulfates on New York, including the ways in which transported sulfates interfere with and prevent New York's compliance with the Clean Air Act. It will also examine the evidence of the transport phenomenon as it relates to New York State. Finally, data indicating that reduced SO_2 emissions will result in reduced downwind sulfate levels is reviewed.

These comments will focus on sulfates, as they are widely monitored throughout New York and the region in general. They serve as a surrogate for the variety of primary and secondary fine particulates originating from coal-fired power plants. In addition, the health and ecological effects of sulfate pollution has been well documented. The other particulate species have their own adverse impacts, too numerous and diverse for detailed consideration here.

The population and resources of the State of New York suffer a variety of adverse impacts from sulfates transported from midwestern sources. Sulfates are deposited in both the wet and dry modes and cause:

(1) health injuries to the population of New York State,

(2) severe and irreparable damage to aquatic ecosystems in the Adirondack region.

(3) demonstrable effects on terrestrial flora and fauna, including commercial crops,

(4) significant degradation in visibility throughout the state, and

(5) damage to a variety of materials, including valuable works of art and historic monuments.

While high ambient sulfate levels affect the entire State, the regional weather patterns and local geological formations of the Adirondack Mountain region make it particularly vulnerable.

A. Human Health Effects.

There are two major routes by which sulfates adversely affect human health. One type of health insult results from the various effects of acidified water and the other from inhalation of sulfates and associated pollutants in the ambient air.

1. Acidified Water. Precipitation which has been acidified by sulfates has increased the corrosivity of public and private drinking water supplies to the point where excessive levels of copper and lead are leached from pipes and solder joints. Concentrations of these metals in drinking water sources in the Adirondack region have been found to exceed federal drinking water standards, leading to the issuance of a Health Advisory notice by the N.Y. State Department of Health.* Such corrosive waters have been identified throughout the New York counties of Herkimer, Franklin, Hamilton and Fulton plus parts of St. Lawrence, Oneida and Essex Counties.

Dr. Wolfgang Fuhs, Director of the Environmental Health Center, New York State Department of Health, has provided additional information regarding the interrelationship between acid rain and heavy metal contamination of drinking water. He describes two cases of children having elevated levels of lead in their blood apparently attributable to their home water supplies. This material, together with a recent report from the Department of Health indicating the source of ambient sulfates in the Adirondack region is included as Attachment A to this petition.

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* Fuhs, G.W., "A contribution to the assessment of health effects of acid precipitation." In Proceedings of the Action Seminar on Acid Precipitation, Nov. 1-3, 1979, Toronto, Canada.

Dr. Norman R. Glass, Director of the EPA Environmental Research Laboratory in Corvallis, Oregon, has reported that acid precipitation accelerates the dissolution of various toxic heavy metals from soils and is thereby causing increased concentrations of these substances in affected lakes.* Of course, such contaminated runoff may also drain into water supply systems, contributing to drinking water contamination.

The concentration of mercury in the edible flesh of fish from two Adirondack lakes is so high that the New York State Department of Health has issued a Health Advisory warning the general public to limit consumption of these fish.* Pregnant women and nursing mothers were advised to avoid eating these fish entirely. The New York State Department of Environmental Conservation (DEC) has found that the level of mercury in fish from Adirondack lakes has increased 20 - 100% during the last 10 years, in spite of the fact that the mercury levels in fish from other parts of New York have declined.**

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* Glass, N.R. "Environmental effects of increased coal utilization: Ecological effects of gaseous emissions from coal combustion," Envir. Health Perspectives 33:249-272, 1979.

2. Inhalation of sulfates. Ambient sulfates, as respirable particles, have been linked with sickness and death in humans. Dr. Leonard Hamilton, in work supported by the U.S. Department of Energy, has subdivided the extensive literature on this subject into several categories:

1. multi-city regression studies,
2. detailed mortality studies in a particular city,
3. association of daily mortality and daily pollution levels within single cities,
4. studies of disastrous air pollution episodes,

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* Fuhs, G.W., op cit.

** Amstrong, R.W. and R.J. Sloan, Trends in levels of several known chemical contaminants in fish from New York State waters, N.Y. State Dept. of Environmental Conservation, June 1980.

5. experimental animal studies,
6. individual morbidity studies,
7. occupational studies, and
8. experimental human studies.

As a whole, these studies provide compelling evidence of health dangers from fine sulfate particles.* It has been estimated that sulfates account for almost 187,000 deaths per year among the adult white population of the United States.** In the northeastern and northcentral regions the probability of dying from air pollution is twice as high as in the rest of the country.***

Experimental, short-term exposure of humans and donkeys to acid sulfate aerosols has led to persistent disturbance in bronchial mucociliary clearance.**** Such interference with the physiological defense mechanisms of the respiratory system has been clearly linked with the pathogenesis of chronic bronchitis.***** This data indicates that acid sulfate inhalation is a causal agent for the chronic bronchitis and perhaps the associated morbidity and excess mortality noted in numerous epidemiological studies. When sulfate particles are inhaled, they are carried well down into the respiratory system, bringing other pollutants with them.* Since acid sulfates decrease the efficiency of clearance of the respiratory system,** the accompanying toxic substances remain there longer and are more likely to be absorbed.

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* Hamilton, L.D., "Health Effects of Electricity Generation." Paper presented at the Conference on Health Effects of Energy Production, Ontario, Canada, Sept. 1979.

** Mendelsohn, R. and G. Orcutt, "An empirical analysis of air pollution dose- response curves," J.Envir. Econ and Mgt. 6:85-106, 1979.

*** Ibid.

**** Lippman, M. et al., "Effects of sulfuric acid aerosols on respiratory tract airways." Paper presented at the Fifth British Occupational Hygiene Society International Symposium on Inhalod Particles, Cardiff, Wales, Sept. 1980.

***** Ibid.

B. Destruction of animal populations

In 1976, 51% of 217 Adirondack region lakes at an elevation above 2000 feet had pH values below 5.0. There were no fish in 90% of these acidified lakes, although during the period of 1927-37 only 4% of these lakes were similarly acidified and devoid of fish. The species which were eliminated from these lakes included brook trout, lake trout, white sucker, brown bullheads and several cyprinids.***

Festa and Pfieffer of the New York State Department of Environmental Conservation (DEC) have surveyed 849 of the almost 3000 lakes in the Adirondack ecological zone. In addition to the high altitude lakes of the 1976 study, they also surveyed a number of low altitude lakes which are known to be less sensitive to the impact of acid precipitation. In this sample, designed to be conservative, 25% of the lakes had a summer surface pH below 5.0.* At that pH level there is almost complete extinction of fish populations.** An additional 30% of the lakes had a summer surface pH of 6.0-5.0, and fish populations in these lakes are considered to be endangered. Therefore, only 45% of the lakes in the Adirondack region had a satisfactory summer surface pH.***

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* In addition to sulfates, coal-fueled power plants emit a variety of other toxic air pollutants, including polycyclic aromatic hydrocarbons (PAH) and trace elements such as lead, mercury, beryllium, cadmium and arsenic. These other pollutants, emitted as gases due to the high combustion temperatures, can be absorbed or condensed onto fine particulate matter. Perera, F.P. and A.K. Ahmed, *Respirable Particles Impact of Airborne Fine Particulates on Health and the Environment*, Ballinger Publ. Co., Cambridge, Mass. 1979.

** Lippman, M. *Et al.*, *op. cit.*

*** Schofield, C.L., "Acid precipitation: effects on fish." *Ambio*, 5:228-230 (1976).

Experimental evidence indicates that decreased pH due to acid precipitation inhibits reproduction and kills young fish. In addition, lowered pH leaches aluminum from the soil into the water, thus increasing concentrations of aluminum, which also contributes to fish mortality.**** Thus, at least two of the causes of the fish mortality in acidified lakes have been experimentally verified.

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* Pfeiffer, M.H. and P.J. Festa, Acidity of Lakes in the Adirondack Region of New York in Relation to Fish Resources, N.Y.S. Dept. of Environmental Conservation, August 1980.

** Schofield, C.L., op. cit.

*** Pfeiffer, M.H. and P.J. Festa, op. cit.

****Schofield, C.L., "Processes limiting fish populations in acidified lakes," Chap. 16 in Atmospheric Sulfur Deposition - Environmental Impact and Health Effects, D.S. Shriner, C.R. Richmond and S.E. Lindberg, eds. Ann Arbor Science Publishers, Inc. 1980.

Decreasing pH in the range of 6.0 - 5.0 will cause the elimination of many aquatic plant and animal species and thus the disruption of the existing biological communities.* Such disruption may reduce the total food resources available to fish, or force them to shift to less beneficial foods, thus subjecting them to competitive and nutritional stress. At pH 5, major extinctions of fish populations, as explained above, will commence, and below pH 4.5 no fish species will survive.**

It has recently been estimated that the loss of annual fisheries values to licensed New York resident anglers may be as high as $6.4 million annually for the Adirondack fishery.*** Reduction in resident angler expenditures would add an additional $1 million to the annual losses in this region.**** These figures do not include additional expenditures for reclamation or the millions of dollars spent on research conducted on acid deposition. Research expenditures within the Adirondack Park region alone, for Fiscal Year 1980-81, are estimated at $2.5 million.*****

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* Hendrey, G.L., et al., Geological and Hydrochemical Sensitivity of the Eastern United States to Acid Precipitation. EPA 600/3-80-024, January 1980.

** Ibid.

*** Menz, F.C. 1981. The Economic Significance of Acid Deposition in New England/New York. Report prepared for the N.Y. State Dept. of Law, September 1981. (This report is included as Attachment B to this petition.)

**** Ibid.

***** La Bastille, A., Commissioner of the Adirondack Park Agency, Communicated in telephone conversation to Michael Surgan, Ph.D. Environmental Scientist, New York State Department of Law.

In terrestrial ecosystems, acid precipitation has been shown to have a dramatic effect on the reproduction of several amphibian species endemic to the Adirondack region. Eggs of some salamanders showed a pre-hatching mortality of 80% or more when incubated in acidified water comparable to their normal breeding pools.*

C. Effects on plant life

Recent experiments indicate that ". . . acid precipitation can damage foiliage; accelerate cuticular erosion; alter responses to associated pathogens, symbionts and saprophytes; affect the germination of conifer and hardwood seeds and the establishment of seedlings".**

Acid rainwater mobilizes toxic heavy metals in the soils, which may then be absorbed by plants.*** Nutrient substances are leached from the soil by acid rain.**** In non-cultivated lands such loss of minerals must be considered irreversible. Acid rain also causes changes in the bacterial and fungal communities which maintain the critical cycling of nutrients in the soil.*****

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* Pough, H., "Acid Precipitation and Embroyonic Mortality of Spotted Salamanders, Ambystoma maculatum," Science 192; 68-70, 1976.

** Glass, N.R., et al, "The ecological effects of atmospheric deposition." From: EPA. ORD Decision Series, Energy/Environment III, EPA 600/9-78-022, October 1978.

*** Altshuller and McBean, 1979, op. cit.

**** Ibid.

***** Raynal, D., Effects of acid precipitation on a forest ecosystem in the Adirondack mountains, Report to the N.Y. State Energy Research and Development Authority, 56/ES-EHS/79, Dec. 1980.

Although definitive studies documenting agricultural (including apples, grapes and various field crops) and forest product losses in New York State are yet to be published, the potential for damage is clearly present.*

D. Effects on Visibility

As fine particles, sulfates scatter light very efficiently and thereby interfere with visibility by reducing the intensity of light and causing color distortion. EPA recently reported to the Congress: "Historical trends and other empirical [sic] and analysis provide strong support for a proportional relationship between regional SO_2 emissions and sulfate/visibility im[illegible] ..."** Visibility in the western states often approaches 200 Km and regularly extends to 100 Km in rural settings.*** However, sulfur mist from power plants is contributing significantly to poor visibility in the northeast, where it averages less than 13 Km.**** Discussing regional visibility in the East, EPA stated that ". . .regional trends in visibility are strongly associated with regional sulfur oxide emissions, especially from power plants."* Therefore, by EPA's own reasoning, increased SO_2 emissions in the Midwest contribute to further degradation of visibility in New York State.

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* For example, see Lee, et. al., (1980) "Sulfuric acid rain effects on crop yield and foliar injury." U.S.E.P.A. 600/3-80-016, cited in Altshuller, A.P. & G.A. McBean "Second report of the United States - Canada Research Consultation Group on the long-range transport of air pollutants," Oct. 1980.

** "Protecting Visibility - An EPA Report to Congress", EPA-450/5-79-008, October 1979.

*** Glass, N.R., op, cit.

**** Costle, D.M., "Acid Rain" The time to act is now." Remarks presented at: Acid Rain Conference with the States, Springfield, Va., April 8, 1980, see Attachment C.

In its report to the Congress, EPA recognized that reduced visibility affects a variety of economic, phychological and social/political values.** Reduction in visibility represents a degradation in the quality of life for all residents of New York State. It tends to reduce revenue from tourists and adversely affect property values in scenic areas. As EPA reported

> Studies of trends in Eastern airport visibility indicate that overall Eastern visibility declined. Summer, often the season of best visibility in the early fifties, is currently the worst season. From 1948 to 1974, summertime haze (extinction) increased by more than 100 percent in the Central Eastern States....***

Moreover, in the long term, there are climatological effects of light dispersion.**** Reduction of available sunlight reduces the potential for solar energy production in New York State, where the increasing price and demands on traditional energy sources dictate the development of alternative technologies.

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* "Protecting Visibility - An EPA Report to Congress", EPA 450/5-79-008, October 1979.

** Ibid.

*** Ibid.

**** Higgins, I.T.T., Airborne Particles, National Academy of Sciences, Washington, D.C. 1977.

The reduction of sunlight available for plant photosynthesis, alterations in the length of growing seasons and changing precipitation patterns, all influence the agriculture and forest productivity of New York State. Further information regarding the impact of imported sulfates on visibility in New York State is presented in Section II of this document. Detailed analyses are presented in the appended report by Dr. Perry Samson (Attachment D).

E. Effects on materials

Acid sulfates contributed to the deterioration of a variety of metals, exterior paints, limestone, marble, mortar, concrete, textiles (both synthetic and those of plant origin), paper and leather.* The loss in damage to artistic works and historic structures is also very serious, costly, and often permanent.

The total cost borne by the people of New York for maintenance and replacement of materials has not been quantified, but it is certainly very great.** Recent expert testimony before the Senate Small Business Committee indicated that:

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* Glass, N.R., "Environmental Effects of Increased Coal Utilization: Ecological Effects of Gaseous Emissions from Coal Combustion," Environmental Health Perspectives 33: 249-272, 1979.

** It has been estimated that the costs of the corrosion of metals by atmospheric sulfur pollutants totaled more than $7. *per capita* in the U.S. in 1970. Considering the increased transport of such pollutants into New York and the effects of inflation, the current costs to New York must be considerably higher. Likens, G.E., "Acid Precipitation," Chemical and Engineering News 54; 29-44, 1976.

> . . .[t]he 1978 value of the effects of acid precipitation on the current annual yields of existing economic activities in the eastern third of the United States is no more than $5 billion. Our best estimates are that $2 billion is in materials effects, $1.75 billion is in forest ecoysystem effects, $1 billion is in direct agricultural effects, $0.25 billion is in aquatic ecosystems effects, and $0.10 billion is in other effects, including health and water supply effects.
>
> We are unconvinced that either the above ordering or the absolute magnitude estimates of the current annual benefits constitute the really important issues to consider when evaluating the acid precipitation problem. Indeed, we are left with the disquieting feeling that the effects for which one may feel secure using our simple, or even the much more sophisticated but still conventional, methods of economic analysis are those having the least economic significance: the ultimate economic losses could be much larger. In fact ours and similar estimates can be a misleading basis for control decisions for at least three reasons: incremental damages that decline with increasing acidification; irreversibilities; and the values of natural resource assortments that our techniques fail to capture.* (Emphasis added)

This estimate may be conservative. An Acid Deposition Task Force of the Wisconsin Department of Natural Resources reported that degradation of material objects alone results in a loss of approximately $13 billion annually in the eastern United States.** Dr. Frederic Menz has commented on the economic impact of acid deposition on aquatic ecosystems, water supplies, terrestrial ecosystems, man-made materials and visibility (See Attachment B). His report further elaborates on some of the criteria which should be applied to obtain a meaningful estimate of the economic consequences of acidic deposition. Many other impact estimates prove to be woeful underestimates when measured against these criteria.

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* Statement by Dr. Thomas D. Crocker, Professor of Economics, University of Wyoming, Laramie, before U.S. Senate Small Business Committee and U.S. Senate Committee on Environment and Public Works, Sept. 23, 1980.

** Tschirhart (1980) cited in "A review of acid deposition in Wisconsin; Recommendations for studying and solving the problem." Prepared by Department of Natural Resources Acid Deposition Task Force, June 1980.

F. The National Academy of Science report on ecological consequences of fossil fuel combustion supports New York's conclusions regarding the effects of sulfate pollution.

The foregoing discussion has indicated the scope of the physical and economic damage which acid rain causes in New York State. It is appropriate to briefly consider the Scandanavian experience with acid rain, which has been studied extensively and documented even more clearly than that of the northeastern United States. Since the 1950's the acidity of precipitation in some parts of Scandanavia has increased 200 fold.* In southern Scandanavia, 75% of the trout and salmon fisheries have been lost.** It has been estimated that acid rain caused an overall timber growth loss of 2-7% per year in southern Sweden.*** Although damage due to acid rain has not been documented to this extent in New York, it is alarming to note that bacteria and fungus found in some Adirondack soils are more similar to those in Swedish soils than in other North American samples.**** Moreover, effects are cumulative and elusive and at some stage recovery may be impossible.***** It is unconscionable to delay action until such destruction has occurred.

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* Likens, G.E., et al., "Acid Rain" Sci. Am. 21, 43-51, 1979.

** LaBastille, A., "Report on acid precipitation" Adirondack Park Agency, July 1979.

*** Cowling, E.B., "Testimony of Dr. Ellis B. Cowling," Hearings before the Subcommittee on Oversight and Investigations of the Committee on Interstate and Foreign Commerce, House of Representatives, U.S. Congress, Feb. 26 & 27, 1980.

**** Raynal, D., 1981, op. cit.

***** Altshuller, A.P. & G.A. McBean, 1979, op. cit. p. 20.

The National Research Council, an affiliate of the National Academy of Sciences, has recently released a report on the ecological consequences of fossil fuel combustion. Prepared by an independant committee of highly respected scientists, this report recognizes the links between power plant emissions and their adverse effects downwind. The authors further recognize the continuum of effects exerted by these pollutants in the ambient air and in the soil and water when they are deposited. Their conclusions support the position taken by New York and are especially pertinent to the present discussion:

> "Perhaps the first well-demonstrated widespread effect of burning fossil fuel is the destruction of soft-water ecosystems by 'acid rain,' which has been caused by anthropogenic emissions of sulfur and nitrogen oxides that are further oxidized in the atmosphere. Major effects include destruction of many species of fish and their prey and acidification of surface and ground waters to the point where toxic trace metals reach concentrations undesirable for human consumption and for aquatic animal habitats (see Chapter 8). Severe degradation of many aquatic ecosystems has been recorded in Norway, Sweden, the United States, Scotland, and Canada (Drablos and Tollan 1980). Surprisingly, significant effects have also been recorded for aquatic systems in countries once thought to be geologically resistant to acidification, including the Netherlands, Denmark, and Belgium (Vangenechten and Vanderborgth 1980, Van Dam et al. 1980, Rebsdorf 1980).
>
> Although claims have been made that direct evidence linking power-plant emissions to the production of acid rain is inconclusive (Poundstone 1980, Curtis undated), we find the circumstantial evidence for their role overwhelming. Many thousands of lakes have already been affected, according to estimates by European and North American scientists (Drablos and Tollan 1980). Acidified lakes have been found in areas where geological factors, such as volcanism and the weathering of pyrites, or biological factors, such as acid bog drainage, cannot be implicated. At current rates of emission of sulfur and nitrogen

> oxides, the number of affected lakes can be expected to more than double by 1990, and to include larger and deeper lakes (Henriksen 1980). There is little probability that some factor other than emissions of sulfur and nitrogen oxides is responsible for acid rain. Although the deposited nitrogen and sulfur may be slightly beneficial in terrestrial soils deficient in these elements, the stimulus is expected to be short-lived (Abrahamson 1980), and over the long-term acid precipitation is likely to accelerate natural processes of soil leaching that lead to impoverishment in plant nutrients (Overrein et al. 1980). When freshwater effects are considered, the positive effects are greatly outweighed by the negative.
>
> The same gaseous oxides are known to affect human health directly in urban areas (Lave and Seskin 1977, NRC 1977b, NRC 1977c, NRC 1978a, Mendelsohn and Orcutt 1979) and to cause decreases in crop yields in some areas. Acid deposition is also known to cause large economic losses by corroding metals and eroding buildings and statuary made of calcareous rock (Bolin 1971, Nriagu 1978). The Committee believes that continued emissions of sulfur and nitrogen oxides at current or accelerated rates, in the face of clear evidence of serious hazard to human health and to the biosphere, will be extremely risky from a long-term economic standpoint as well as from the standpoint of biosphere protection."*
> (Emphasis added)

In regard to amelioration, the National Research Council concludes: "Control of SO_2 from new electrical generating plants alone would be insufficient to accomplish this and thus restrictions on older plants must be considered."**

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* Atmosphere-Biosphere Interactions: 'Toward a Better Understanding of the Ecological Consequences of Fossil Fuel Combustion. Report by the Committee on the Atmosphere and the Biosphere, National Research Council. National Academy Press, Washington, D.C. 1981.

** Ibid.

II. SULFATES ARE TRANSPORTED FROM MIDWESTERN STATES TO NEW YORK

In the 1977 Amendments of the Clean Air Act, Congress established the National Commission on Air Quality ("NCAQ") to review the progress of the Act.* In the past year, the NCAQ has confirmed that sulfur dioxide emissions adversely affect distant downwind areas. One of the findings in the NCAQ's report is that the long-range transport of "secondary particulate matter" (sulfate particles formed by the chemical transformation of sulfur dioxide) can contribute significantly to the failure of a downwind area to meet the national ambient air quality standards.** The NCAQ also found that sulfate particulates formed from SO_2 emissions can be transported to areas 1,000 kilometers from the sources, thereby contributing to particulate loading, acid deposition and visibility impairment, and hindering efforts to improve air quality through local regulatory programs in the downwind area.***

The NCAQ's report concluded that the problem of transported pollutants is one of the two main reasons why air quality in certain areas of the country will continue to violate national ambient air quality standards.****

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*Section 323, 42 U.S.C. § 7623.

**NCAQ op. cit. p. 2.1-2.7 (Supp. Doc. No. IX-A-4-a[a][q]).

***Ibid., p. 2.1-69 & 70, Doc. No. 64.

****Ibid., p. 3.4-27.

A. Major EPA sponsored reports indicate that New York receives sulfate pollutants transported from the Ohio River Basin.

In many areas of New York, sulfates represent a high percentage of the measured TSP levels. Studies show that these sulfates are, for the most part, the result of gas-to-particle conversion of sulfur dioxide emissions from midwestern sources during long-range transport. Documentation of the transport of midwestern sulfates to New York has been done by several different groups, whose research is readily available to EPA.

EPA has funded and directed a series of studies which are collectively known as the Ohio River Basin Energy Study (ORBES).* One ORBES study, entitled "Impact of Long-range Transport of Pollutants on Air Quality in the Commonwealth of Pennsylvania," concluded that the failure to attain the NAAQS for particulates in Pennsylvania is the result of a regional SO_2 emission problem. The study suggested that it may be necessary to restrict emissions from sources outside Pennsylvania in order to attain standards within that state.* The long-range transport data and wind trajectory analyses in this and other ORBES reports have clearly indicated that a similar level of sulfates is carried into western and central New York and perhaps even into eastern/metropolitan areas.** Thus, the ORBES conclusions*** support the idea of transport of sulfates to New York from midwestern SO_2 sources.

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*ORBES was undertaken by EPA in 1975, under direction from Congress. Senate Report No. 94-326, of the Senate Committee on Appropriations, to accompany H.R. 8070, July 24, 1975. The prime contractor for EPA on the air pollution problems of the study was Teknekron, Inc. of California which prepared most of the studies concerning long-range transport of air pollution. See Stukel & Keenan, ORBES Phase I: Interim findings, EPA Office of Research & Development, Office of Energy Minerals and Industry, November 1977, EPA 600/7-77-120.

One major component of the study was to assess the current and future air pollution impacts of the electric power industry in the states of Illinois, Indiana, Ohio, Kentucky, West Virginia and Pennsylvania. The study is now completed and a final report has been distributed. Preceding this final report were many scientific papers, several of which specifically addressed the long-range impacts of midwest sulfur dioxide emissions.

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*Nieman and Mahan, Teknekron, Inc., Interim Report May 1980, prepared for the U.S.E.P.A. Office of Energy Minerals and Industry.

**See, Smith & Nieman, "ORBES - The Future of Air Resources and Other Factors Affecting Energy Development, Paper #2 - Recent Airport and Tower Meteorological Data," (1979), for EPA office of Research & Development RM-066-EPA-79; Mahan, Nieman & Phillips, "Characteristics and Origins of SO_2 Total Suspended Particulates and Sulfates in Western Pennsylvania," June 1979, R-019-EPA-79 prepared for EPA Office of Energy Minerals & Industry, and Pennsylvania Department of Environmental Resources. (This last document is included in record of this hearing.)

***Also included in the record are portions of the following documents:

Main report, Ohio River Basin Energy Study, U.S. EPA Office of Engineering and Technology. January 1981.

Documentation in Support of Key ORBES Air Quality Findings, Ohio River Basin Energy Study, Vol. I. Air Quality and Related Impacts, Teknekron.

Draft: Air Quality and Meteorology in the Ohio River Basin, Baselene & Future Impact ORBES Vol. II, Air Quality and Related Impacts, Teknekron.

B. Pollutant monitoring and trajectory analyses support the Midwestern origin of sulfates transported into New York.

The impacts on New York State indicated by the ORBES reports were further confirmed by an EPA study of the particulate problem in the Niagara Frontier Air Quality Control Region (AQCR) of western New York.* That study, Particulate Source Contributions in the Niagara Frontier, concluded that sulfate and other fine sulfur particles found in the Niagara frontier are "most likely representative of long-range transport of material arising from gas to particle [i.e. SO_2 - SO_4] conversion processes." The EPA report goes on to say:

> One concludes that major emissions of sulfur particulates from industrial processes are not readily discernible in project data, and local sources may be negligible despite such activities as coking and use of bulk sulfuric acid. After consideration of wind direction data, it is concluded that 75% of all sulfate material enters New York State from west of Buffalo ... .**
>
> From this data it appears that the sulfate component of IP [Inhalable Particulates] (or TSP) is not significantly affected among the urban sites by heavy industrial operations or heavy vehicular activities... . Such behavior for the sulfate component is more consistent with the long-range transport of sulfates into New York State from the predominantly southwesterly winds.***

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*Kolak, Hyde & Forrester, Particulate Source Contributions in the Niagara Frontier, prepared for U.S.E.P.A., Region II, Air Programs Branch, E.P.A. 902/4-79-006, December, 1979. For a similar finding on a regional scale see Altshuller & McBean, 1979, op. cit., p. 9. A copy of portions of this report are included in the record of this proceeding.

**Kolak, Hyde & Forrester, op. cit., p. 2-3, (Emphasis added).

***Ibid., p. 7-6 (Emphasis added).

This study also demonstrated that, in spite of their small size and weight, these sulfur particles form a very high percentage of the total suspended particulates in the Niagara frontier region.

Drs. Rao and Sistla, of the New York DEC have recently completed a study entitled "Relationship between urban and rural sulfate levels in the Niagara-Frontier region of New York".* They observed that sulfate levels detected at rural sites generally far upwind of known sources and urban areas in the Niagara Frontier region represented about 75% of the sulfate detected at urban sites. This observation supports the results of Kolak et al. discussed above.

Wolff et al. (1979) characterized aerosols collected upwind of New York City, in High Point, N.J.** This area is sparsely populated and contains no large point sources, and is therefore an ideal location to sample air entering New York City from the west. They concluded that on August 22 and 23, 1976 as much as 74% of the total TSP could have been due to long-range transport. Visibility isopleths plotted for the preceding week indicated that the particulate matter originated in two masses: one over Ohio and parts of Kentucky and West Virginia, and the other over Illinois and the western shore of Lake Michigan. These masses subsequently merged and moved eastward into Western Pennsylvania and New York.

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*Rao, S.T. and G. Sistla, 1981. "Relationship between urban and rural sulfate levels." Preprint of a paper to be published in the Journal of the Air Pollution Control Association.

**Wolff, G.T., P.J. Lidy, B.P. Leaderer, D.M. Bernstein & M.T. Kleinman. 1979. Characterization of Aerosols Upwind of New York City: I. Transport. Ann. N.Y. Acad. Sci. 322: 57-72.

C. Long Range Transport models predict the impact of Midwestern SO_2 emissions on New York.

The magnitude of the imported sulfate burden borne by New York, as indicated by the analyses of Wolff et al. (1979), Kolak et al. (1980) and Rao and Sistla (1981) are further supported by the predictions of numerous long-range transport models. Such models are currently being used by Work Group 2 of the U.S./Canada Work Group on Transboundary Air Pollution. This work group was organized pursuant to the Memorandum of Intent on Transboundary Air Pollution signed by the United States and Canada on August 5, 1980. Signatories to the Memorandum of Intent included the Administrator of the U.S.E.P.A., the U.S. Secretary of State, the Canadian Ambassador to the United States and the Canadian Minister of the Environment. Members of the working groups were appointed based upon their recognized expertise in the various disciplines of concern.

The Atmospheric Modeling Work Group (Work Group 2) has generated transfer matrices for seven different models. These predict the percent of ambient sulfate in specific receptor regions which originated in defined source regions.*

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*Phase II Working Report by Work Group 2, U.S./Canada Work Group on Transboundary Air Pollution, Report #2-13, July 10, 1981.

Each model incorporated specific assumptions on the various modeling parameters, but in toto, they can be expected to represent the collective wisdom of many experts in this field. The results of the individual models were averaged producing a single transfer matrix indicating that more than 90% of the ambient sulfate in the Adirondack region was transported into New York State (see Table 1). An eighth model, developed at the University of Michigan, and in use by the U.S./Canada Work Group, indicates that more than 98% of the ambient sulfate in Dunkirk, N.Y. during July 1978 originated out of state, mostly in the Ohio River Basin.* These modeling efforts are discussed at greater length in Attachment D.

Thus, despite the variations in the parameters incorporated in these models, they are in striking agreement in their conclusions. New York receives a substantial portion of its sulfate pollution from sources outside its borders. This is true of both ambient and deposited pollution. The need for equitable control on the sources of this pollution is clear.

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*See Attachment D, p. 63-68.

TABLE 1. Percent contribution of source regions to ambient sulfate concentrations in the Adirondack region.*

Source Region	Contribution
Michigan	6.57
Illinois-Indiana	10.10
Ohio	16.23
Pennsylvania	10.46
New York to Maine	9.93
Kentucky-Tennessee	3.93
W. Virginia to No. Carolina	7.34
Rest of Eastern U.S.	7.45
Ontario	19.44
Quebec	8.33
Atlantic Provinces	0.22

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*Mean of seven models. From: Phase II Working Report by Work Group 2, U.S./Canada Work Group on Transboundary Air Pollution, Report #2-13, July 10, 1981.

D. Local sources of sulfate cannot account for the observed sulfate levels.

New York has examined its inventory of sources which emit sulfates. They are few and relatively small.

The Chemical Information System (established by the National Institutes of Health and EPA) was queried as to various types of sulphur compounds which are emitted into the air. A total of 2,287 different compounds were discovered to fit this description. New York's Source Management System was searched to determine plants reporting emissions of these compounds.

Plants emitting more than 10 tons of sulfate per year are:

International Paper - Essex County - 250 T/Yr.
Donner-Hanna Coke - Erie County - 16 T/Yr.

In addition, sulfur trioxide reacts as a sulfate and would contribute to measured sulfate concentrations. The large sources of SO_3 in New York are:

Meael Corp. - Westchester County - 21 T/Yr.
Albany County Waste Water Incinerators - Albany County - 49 T/Yr.
Kodak Park - Monroe County - 13 T/Yr.
Buffalo Chemical Plant - Erie County - 125T/Yr.

Thus, emissions of sulfates in New York State are quite small, and disproportionate compared to the high level sulfates measured in the ambient air. Due to the time necessary for conversion of SO_2 to sulfate, local SO_2 sources cannot contribute significantly to local sulfate pollution. Therefore, this inventory supports New York's conclusion that the sulfate levels in New York State are primarily the result of long-range transport from out-of-state sources.

E. New analyses and review of the literature by Dr. Perry Samson confirms and supports the Midwestern origin of a significant portion of New York's sulfate burden.

Dr. Perry Samson, of the University of Michigan, has prepared a report for New York State demonstrating the transport of sulfates and other particulate matter into New York. The report not only reviews the published literature, but presents original analyses of meteorological data, SO_2 emissions inventories and ambient SO_4 measurements. The Ohio River Basin is clearly indicated as the source region for particulate matter having significant impact on New York's ability to attain the secondary National Ambient Air Quality Standard for TSP, as well as on visibility in rural areas. Dr. Samson's report is incorporated, by reference, into the petition at this point, and appended hereto (Attachment D). The balance of this section is a summary of Dr. Samson's findings and conclusions.

Upon review of the pertinent literature, Dr. Samson states that sulfate particles emitted directly from coal-fired power plants, as well as those formed as a result of gas-to-particle conversion, have a potential atmospheric residence time of 80 hours or more. During that time these sulfate particles, and other fine particles emitted from the same sources, can be transported long distances before deposition.

Dr. Samson also examines the distribution of point sources for particulate matter and SO_2 emissions east of the Rocky Mountains. The data shows a striking concentration of such sources in the Ohio River Basin. This area extends from western Pennsylvania to western Kentucky and including most or all of the states of Ohio, Indiana, Illinois, Kentucky, Tennessee and West Virginia. Moreover, the climatology of wind flow in this region shows winds moving northward from the source region and then turning toward the east, with highly persistent winds carrying the pollution into New York State. Dr. Samson demonstrates that when air masses following this pattern experience stagnation, which maximizes gas-to-particle conversion, and little or no precipitation, which would remove particulate matter, they arrive in New York laden with particulate pollution.

These particulate pollution episodes are consistently associated with monitored exceedances of the secondary TSP NAAQS and regional visibility impairment in New York. For example, during the period of 1976-1980, Dr. Samson found that TSP concentrations exceeded the secondary standard in more than one county on the same day, more than 35% of the time. On some days, these exceedances were widespread, occurring at up to 52 different sites statewide. Such widespread pollution episodes cannot be attributed to local sources. There can be little doubt that these episodes are due to transported particulates from distant sources.

Similar regional impacts are apparent when visibility data from upstate airports are analyzed. In spite of incomplete records, Dr. Samson reports that impaired visibility (less than or equal to 6 miles) was recorded on 22% of the possible days during the period of 1976-1980. Several published reports have documented the movement of regions of reported haze from the Ohio River Basin into New York and the Northeast. Quantitative measurements of visibility and satellite imagery have further substantiated this phenomenon. A ten year record of hourly wind and visibility observations confirms the association of regional haze episodes in New York State with winds coming into Buffalo from the southwestern sector.

Trajectory analysis, whereby the path of an air parcel en route to a specific receptor is calculated, is a useful tool to estimate the history of specific air masses. Such analyses have been applied by numerous investigators to determine the origin of many air masses arriving in New York. The specific dates and receptor locations studied have varied, but the conclusions have been consistent. Air masses arriving in New York and bearing high levels of sulfates and other particulate pollutants have tended to originate in the high SO_2 emission regions of the Ohio River Basin and have experienced some period of stagnation before arriving at the New York receptor. Air masses carrying low levels of these pollutants tend to arrive from other directions, frequently from the north and northwest. Although stagnant conditions are important in facilitating the gas-to-particle conversion, repeated observations confirm that high sulfate episodes in New York are correlated with stagnation far upstream. Stagnations near the sampling point do not result in elevated sulfate concentrations, providing further evidence that the source is non-local.

In addition to previously published trajectory analyses, Dr. Samson has provided new analyses using a recently developed trajectory model noted for its reduced sensitivity to observational errors. These case studies focus on days when TSP levels exceeded the secondary NAAQS in more than one air quality district in New York State. These episodes are clearly regional, and not responses to local sources. Trajectories were computed up to 72 hours upwind of Buffalo and Albany. Trajectories associated with sites reporting

TSP exceedances were again consistently traceable to the Ohio River Basin. It is estimated that some of these air masses brought more than 40 ug/m^3 of sulfate into New York State. It is interesting to note that on one date the western end of New York received air from the Ohio River Basin while the air in the eastern end arrived from a broader and more eastern region. TSP exceedances occurred only in the western half of the state on that date.

It is often assumed that in urban areas with significant local sources, the transported fraction of TSP is insignificant and undetectable. However, a comparison of sulfate levels measured in rural Jamestown, in southwestern New York, with those in Buffalo make a dramatic point. On days when sulfate levels above 150 ug/m^3 were measured in Buffalo, there is good correlation between the sulfate levels in the two cities. Thus, in spite of local sources in Buffalo, regional air quality conditions make a notable contribution to Buffalo TSP air quality problems.

Trajectory analyses thus show a correlation between elevated sulfate concentrations, elevated TSP concentrations and TSP exceedances in New York with air masses arriving from the west to southwest, that is, the Ohio River Basin. Dr. Samson has prepared probability fields by consideration of air mass trajectories and regional emissions potential which shed further light on the situation. Although nearby sources may seem likely to have a greater impact on a particular receptor, when considerations of total emissions, meteorological conditions and temporal changes are included, the Ohio River Basin is once again indicated as the source of a significant portion of New York's particulate burden.

Diagnostic trajectory analysis provides even more conclusive evidence of the midwestern origin of New York's imported sulfate. This sort of analysis will reveal correlations between the pollutant load in a particular air mass, with SO_2 emissions and meteorological conditions upwind along the specific trajectory followed by that air mass. Dr. Samson determined air trajectories arriving in Dunkirk, N.Y. (a rural town in southwestern N.Y.) for days when particularly high sulfate concentrations were detected in Dunkirk. Sulfur dioxide emissions, ambient sulfate concentrations and precipitation along the trajectories were determined from available data bases. The dominant feature which emerges from these analyses is a clear and dramatic increase in ambient sulfate concentrations in the air masses as they passed over the Ohio Valley, before they entered New York.

The magnitude of impact of emissions in one area, on downwind receptors can be examined through the use of available regional-scale models. Such modeling is currently being used in the United States and could be applied to estimate the best plans for emissions control to reduce interstate transport of air pollutants. EPA has already evaluated and recommended models for long range transport applications. EPA has not, however, used such models to assess the impact of midwestern emissions on New York.

In addition to the models evaluated and approved by EPA, other models are available. The Atmospheric Modeling Working Group of the U.S./Canada Work Group on Transboundary Air Pollution is using several models to evaluate the environmental impact of fossil fuel usage in the United States and Canada. Adequate data bases for their operation are available. All of these models are currently fully operational, numerically practical and at least partially validated by comparison with measurements. Transfer matrices expressing the impact of source regions on receptor regions have been developed. The application of these models to the sources of New York's sulfate pollutants has been briefly discussed in section II C, above. Additional detail is provided in Dr. Samson's report. These models can be used to design pollution control strategies. In spite of the availability of numerous appropriate models, EPA has not applied them to the regulatory decisions before them.

In summary, based upon a review of published literature and original analyses of appropriate data, Dr. Samson concludes that:

1. exceedances of the secondary NAAQS for total suspended particulates are, in large part, due to elevated pollutant levels in air masses entering New York from outside the State, particularly those originating in the industrialized region of the midwestern U.S., and,
2. increases in sulfate concentration in these air masses are significant and are related to passage over areas of high SO_2 emissions, and
3. these upwind influences on New York State air quality are significant and consistent, and
4. this imported burden forces New York to bear additional effort to maintain National Ambient Air Quality Standards, and
5. appropriate modeling tools are available to EPA for use in the development of strategies to mitigate these impacts.

III. RESTRICTIONS ON SO_2 EMISSIONS WILL RESULT IN DECREASED SO_4 LEVELS DOWNWIND

The transformation of sulfur dioxide to sulfate in the atmosphere may occur via several different chemical pathways. Individual reactions may be influenced by SO_2 and copollutant concentrations, humidity, sunlight intensity and atmospheric stagnation. Although the variety of contributing factors may tend to mask the precise relationship between SO_2 emissions and sulfate concentrations attained downwind, a positive correlation remains clear.

The positive correlation between SO_2 emissions and downwind sulfate levels has been demonstrated under natural, ambient atmospheric conditions in the southwestern United States. Reductions in SO_2 emissions resulted in significantly lower levels of ambient sulfate at downwind receptors. EPA summarized one such event in a report to Congress:*

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*"Protecting Visibility - An EPA Report to Congress", EPA 450/5-79-008, October 1979. p. 4-24.

> "In the late 1960's copper smelters accounted for approximately 90 percent of the sulfur oxide emissions in the Rocky Mountain Southwest (Marians and Trijonis). The 9 month industry-wide shutdown of the smelters during a labor strike (July 1967-March 1968) provided a unique opportunity to investigate the relationship between SO_2 emissions and regional visual air quality.
>
> Trijonis and co-workers examined regional changes in sulfate concentrations and visibility during the strike. As shown in Figure 4-13, substantial decreases in sulfate occurred at five locations (Tucson, Phoenix, Maricopa County, White Pine, and Salt Lake City) that are within 12 to 70 miles of copper smelters. More notably, sulfates evidently dropped by about 60 percent at Grand Canyon and Mesa Verde: these class I areas are located 200-300 miles from the main smelter area in Southeast Arizona." (Fig. 4-13 referred to above appears on the next page as Fig. 1)

Figure 2 illustrates the dramatic shift in the frequency distribution of sulfate concentrations during the strike.

EPA's report to Congress emphasizes that many of the changes in sulfate and visibility during the copper strike are statistically significant at extremely high confidence levels. This statistical significance was further supported by step functions in time series data for visibility (see Figure 3). Note that increased production after the strike, and the concurrent increased SO_2 emissions resulted in an increase

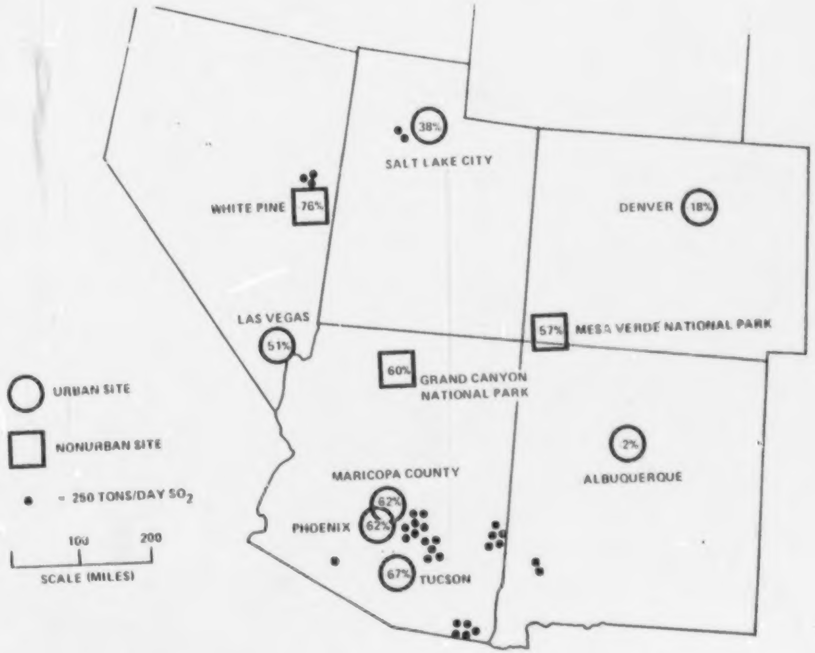
WHITE PINE
76%
SALT LAKE CITY
38%
DENVER
18%
LAS VEGAS
51%
57%
MESA VERDE NATIONAL PARK
60%
GRAND CANYON NATIONAL PARK
2%
ALBUQUERQUE
MARICOPA COUNTY
62%
PHOENIX
62%
67%
TUCSON
URBAN SITE
NONURBAN SITE
= 250 TONS/DAY SO_2
100
200
SCALE (MILES)

Figure 1. Seasonally adjusted changes in sulfate during the copper strike of 1967-68 compared to the geographical distribution of smelter SO_x emissions (Trijonis and Yuan, 1978a). From "Protecting visibility - An EPA Report to Congress" EPA 450/5-79-008, Oct. 1979

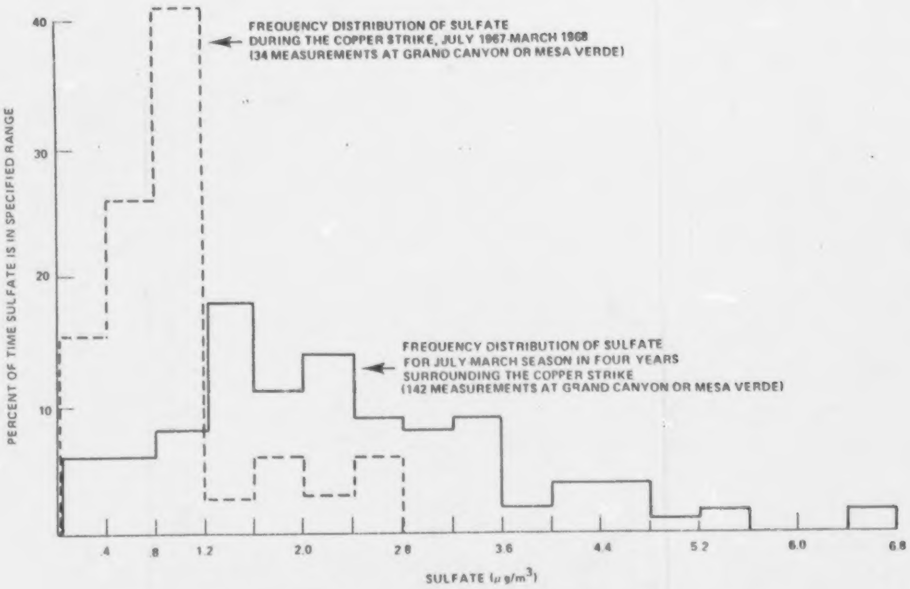

Figure 2. Frequency distribution of sulfate concentrations during the copper strike compared to seasonal average distribution for Grand Canyon and Mesa Verde data combined. Most sulfate measurements fell below 1.2 ug/m^3 during the strike (Trijonis and Yuan, 1978a). From: "Visibility - An EPA Report to Congress." EPA 450/5-79-008, Oct. 1979.

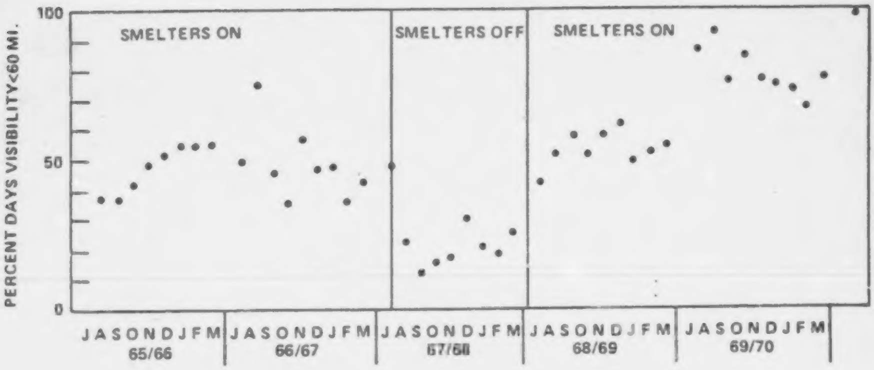

Figure 3. Changes in number of hazy days at Tuscon during the 1967-1968 copper strike. The number of hazy days before the strike (about 50%) fell to about 20 percent during the strike and rose to about 80 percent during the following year when copper production expanded substantially (Hartmann, 1972). From: "Visibility - An EPA Report to Congress." EPA 450/5-79-008, Oct. 1979.

in downwind haze. Therefore, both decreases and increases in SO_2 emissions produced the logically anticipated impacts on sulfate levels and visibility.* Reduced SO_2 emissions resulted in lower sulfate levels at such rural areas as Grand Canyon National Park and Mesa Verde National Park. Visibility in Tucson Arizona was improved markedly. As SO_2 emissions were restored, so were levels of downwind sulfate pollution and visibility degradation.

The correlation between alterations in SO_2 emissions and downwind sulfate levels demonstrated by the Copper Smelter Strike of 1967-1968 was confirmed during the 1980 Copper Smelter Strike. Eldred et al (1981) measured the ambient sulfate levels downwind of the smelter region before, during and after the 1980 strike.** A decrease of 50-90% in mean summer sulfate levels was observed throughout Arizona during the strike. This decrease is consistent with the observations reported above for the 1967-68 strike.

These decrements in downwind sulfate levels actually might be very conservative estimates of the effect reduced midwestern SO_2 emissions would have on the industrialized Northeast. Copollutants and water vapor contribute to the transformation of SO_2 to SO_4; these are prevalent in the Northeast but are not as prevalent in the atmosphere in the Southwest. Therefore, Southwestern transformation rates might be lower than Northeastern rates, minimizing the effect on Southwestern downwind sulfate receptors. With more efficient transformation due to more favorable atmospheric conditions, it is reasonable to anticipate a more dramatic sulfate response in the Northeast.

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*Ibid.

**Eldred, R.A., L.L. Ashbaugh, T.A. Cahill, R.G. Flocchini and M.L. Pitchford. "The Effect of the 1980 Copper Smelter Strike on Air Quality in the Southwest" Preprint of a manuscript submitted to Science, April 1981. (See Attachment E)

Observations on the wet deposition of sulfate have further supported the correlation between increased SO_2 emissions and downwind sulfate levels. Granat (1978) studied the sulfate levels in precipitation observed by the European Atmospheric Chemistry Network (EACN). He concluded that a 50% increase in SO_2 emissions in Europe, during a ten year period, resulted in an increasing amount of sulfur deposition, albeit this deposition occurred outside the geographic range of the established EACN sampling stations.*

EPA is aware of, and has recognized the inevitable relationship between SO_2 and sulfates. In April 1980, Douglas Costle, then Administrator of the EPA stated:

> As a practical matter, the only way to reduce acid precipitation is to reduce emissions of sulfur and nitrogen oxides, the pollutants that cause the problem. Among the major sources of these pollutants are utility power plants.**

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*Granat, L. "Sulfate in precipitation as observed by the European Atmospheric Chemistry Network." Atmos. Environ. 12:413-424, 1978.

**Costle, D. "Acid Rain: The Time To Act Is Now" Remarks at the Acid Rain Conference with the States, Springfield, Va., April 8, 1980 (For full text see Attachment C).

The National Commission on Air Quality also recognized SO_2 emissions control as the rational mechanism for acid rain mitigation. The Commission specifically stated that visibility and ambient air quality would also be improved by reductions in SO_2 emissions:

> ...reductions both in the amounts of sulfur dioxide and nitrogen oxides and in the amounts of compounds that enhance the transformation of these precursor pollutants is expected to result in a lessening of acid deposition, and improvement in visibility, and a reduction in levels of fine particles that are hazardous when inhaled.*

Thus, observations under conditions of both decreased and increased SO_2 emissions have demonstrated that a corresponding change in downwind sulfate will be elicited. The role of meteorological conditions and other contributing factors in the transformation of SO_2 to sulfate need not be fully elucidated before appropriate controls are applied. Reduction of SO_2 emissions will reduce sulfate concentrations downwind of the SO_2 sources.

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*NCAQ op. cit. 2.1-72.

IV. TRANSPORTED SULFATES PREVENT AND INTERFERE WITH TSP ATTAINMENT AND PSD PLANNING

A. Sulfate Levels in New York constitute substantial Portions of TSP levels and significantly contribute to Nonattainment and Maintenance Problems.

Several areas of New York State do not meet the national primary air quality standard for TSP. Numerous other areas are just marginally in compliance. New York State monitoring data demonstrate that sulfates represent a significant portion of the TSP in all areas of the State.* Other studies, also specific to New York State, (See Part II and Attachment D of this report) demonstrate that a large percentage of these sulfates are imported on the prevailing winds from other states to the west and southwest of New York. Monitoring data indicates that the elimination from New York's ambient air of imported sulfate particulates would result in the reclassification of TSP nonattainment areas to attainment status.

For example, in the Niagara Frontier Air Quality Control Region, there were four monitoring sites registering violations of the primary annual TSP standards in 1978 and five such sites in 1979. For the 24-hour standard, 1978 and 1979 data for the region show one monitoring site in violation of the primary standard (i.e. exceeded the standard at least twice within the year) and 13 sites where the secondary standard was exceeded more than once in each year.* (See Table 2).

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*Sulfate is pervasive throughout New York State. Annual sulfate values range from 5.6 - 6.2 ug/m^3 at Cape Vincent, to a high of 11.6 at Buffalo. The natural background level for sulfates ranges from .02 to 2.0 ug/m^3. Coffey, et al., "Summer Aerosol Transport Study", New York State Department of Environmental Conservation, 1977.

The New York State Department of Environmental Conservation (DEC) routinely performs analyses to determine the sulfate portion of the monitored TSP levels for several of the monitoring sites in each air quality region. In the Niagara Frontier, this analysis was performed for two sites in Buffalo and one in Niagara Falls, including one of the Buffalo sites which registered a violation of the Annual TSP Standard in 1978 (78 ug/m^3), and the primary 24-hour standard in 1979.

At that Buffalo site (# 1401-18) the annual sulfate level (geometric mean) was 11.6 ug/m^3 in 1978 and 11.0 in 1979, representing 15 percent of the annual TSP levels in each year.** If this sulfate value were to be subtracted from the annual TSP level, there would have been no violation of the annual standard at this monitor site in 1978. Indeed, even if only one third of this sulfate were removed from the Buffalo atmosphere, there would have been no violation at that site in 1978. This fact is significant in light of the conclusion in a recent EPA funded study which stated that greater than 75 percent of the sulfate levels in the Niagara Frontier air

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* This list includes some sites which measured more than one exceedance of the 150/ug/m standard but are not classified as nonattainment measurements because the national standard is within the statistical probability range for the second highest measured value. Others clearly represented a violation of the standard.

** These were the highest annual average sulfate readings in the State in those two years.

TABLE 2 MEASURED EXCEEDANCES OF NAAQS FOR TOTAL SUSPENDED PARTICULATES IN THE NIAGARA FRONTIER AIR QUALITY CONTROL REGION -- 1978-1979

Station	Site No.	Annual Geometric Mean (Std = 75 ug/m^3) 1978	1979	2nd Highest 24 hour Avg. (Std = 150 ug/m^3) 1978	1979
Lockport	3101-12	--	--	--	157**
Lockport	3101-15	--	--	151**	
Lockport	3101-16	--	--	--	162**
Niagara Falls	3102-07	--	--	218	--
Niagara Falls	3102-09	--	76**	166	221
Niagara Falls	3102-11	97	111	198	220
Niagara Falls	3102-12	--	--	171	--
Niagara Falls	3102-15	--	--	151**	150**
Niagara Falls	3102-01	--	--	160	--
Buffalo	1401-02	--	--	200	175
Buffalo	1401-11	83	86	230	192
Buffalo	1401-18	78	--	209	180
Lackawanna	1402-01	104	100	365	320
Lackawanna	1402-02	--	76**	231	179
Buffalo	1401-30	--	--	222	175
Buffalo	1401-01	--	--	153**	--
Lewiston	3121-02	--	--	170	--
Lewiston	3152-02	--	--	180	--
Niagara	3155-03	--	--	158*	--
Blasdell	1429-02	--	--	--	195
Amhurst	1451-04	--	--	216	219
Cheekta	1455-01	--	--	150**	150**
Tonawanda	1472-04	--	--	184	--
Sloan	1425-01	--	--	152**	--

* This data is reported in the following documents:

1978 -- New York Air Quality Report, Continuous and Manual Air Monitoring Systems, Annual 1978 DAR-79-1, Division of Air, New York State Department of Environmental Conservation; hereinafter referred to as "1978 DEC Air Quality Report."

1979 -- Draft, New York State Air Quality Report, Continuous & Manual Air Monitoring Systems, Annual 1979 DAR-80-1, Division of Air, New York State Department of Environmental Conservation; hereinafter referred to as "1979 DEC Air Quality Report".

1980 -- Air quality data was not yet available at the time this report was prepared.

** denotes that compliance status is indeterminate since either the primary or secondary NAAQS lies within statistical probability range (95% confidence limits) for reported value as established by QA accuracy limits.

quality region originate from the west and southwest of the State border.*

Similarly, the other TSP nonattainment measurements in the Niagara Frontier Air Quality Region would be eliminated or substantially reduced if the high level of sulfates were removed from the atmosphere of western New York. For example, at another Buffalo site (1401-11) the annual violation measurement was 83 ug/m^3 in 1978 and 86 ug/m^3 in 1979. If we subtracted 75 percent of the annual sulfate value** from the 1978 figures, the violation of the annual standard would be eliminated.

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* Kolak, Hyde, Forrester, "Particulate Source Contribution in the Niagara Frontier", by the New York State Department of Environmental Conservation, prepared for U.S. E.P.A., Region II, Air Programs Branch, E.P.A. 902/4-79-006, December, 1979, pages 7-3 and 7-6.

The EPA report noted above also concluded that the sulfate levels were not significantly affected by local heavy industrial operations or heavy vehicular activities. From this data and other reports on the behavior of SO_2 emissions, New York believes it is reasonable to assume that these sulfate levels are predominantly caused by power plant SO_2 emissions in the midwest. Coffey, Galvin, Sampson and Cline, "Summer Aerosol Transport Study-1977", New York State Department of Environmental Conservation, p. 18.

** The annual value of 11.6 ug/m^3 was registered at 1401-18: No sulfate fraction analyses was done for monitoring site 1401-11.

There were 20, 13 and 14 violations of the 24 hours secondary TSP standard in 1978, 1979 and 1980, respectively,* in the Niagara Frontier Air Quality Region. At one monitor site where sulfates are recorded along with TSP, it was determined that in 1978 peak TSP and sulfate levels occurred in the same 24 hour periods of September 11 and May 26, 1978. If the full sulfate value measured on May 26, 1978 (at Buffalo site 1401-01) were subtracted from the TSP value for that day, the exceedance of the secondary standard would be eliminated at that site for the year 1978 (See Table 3).**

Also in 1978 (at Niagara County site 1302-01) the TSP nonattainment readings coincided with high sulfate levels, without which no violation would have occurred:

DATE	TSP (ug/m^3)	SULFATE (ug/m^3)
3/9/78	160	19
5/26/78	174	23.2

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* Included are several readings which do not necessarily demonstrate nonattainment because the national standards are within the statistical probability range for the second highest reported value (95% confidence limit).

** The second highest TSP value of 153 ug/m^3 was measured on that day.

Table 3. Maximum TSP and Sulfate Values

1978

Station	Maximum TSP Values (ug/m^3)			Maximum Sulfate Values (ug/m^3)		
Niagara Falls (3102-01)	174	160	130	48.2	35.0	33.8
Date:	5/26	3/9	11/4	9/11	7/7	8/24
Buffalo (1401-01)	183	153	130	37.9	35.6	34.1
Date:	5/26	7/19	11/4	9/11	8/24	5/26
Buffalo (1401-18)	290	209	200	56.7	56.0	37.6
Date:	5/26	9/11	3/9	9/11	8/24	2/19
Lackawanna (1402-01)	388	365	352			
Date:	4/28	5/18	5/26			

Lackawanna TSP values for: 8/24 - 164
9/11 - No Sample

For September 11, 1978 at Buffalo site 1401-18 elimination of the high sulfate value of 56.7 ug/m^3 from the TSP value would have negated the exceedance of the standard for that day as well as the second highest reading for the year.* For this site in 1979 high sulfates occurred on each of the five days on which the secondary standard was exceeded:

DATE	TSP (ug/m^3)	SULFATE (ug/m^3)
2/20	180	37.8
5/9	227	25.1
6/2	158	44.6
9/16	167	25.3
12/11	168	16.7

Analysis of data from 1980 reveals a similar connection between 24 hour TSP violations (more than 150 ug/m^3) and high sulfate readings in the Niagara Frontier region:

Monitor Location	Site	Date	TSP (ug/m^3)	Sulfate (ug/m^3)
Buffalo	1401-11	7/20/80	159	28.8
Buffalo	1401-18	3/4/80	186	16.1
Buffalo	1401-18	4/21/81	171	15.9
Buffalo	1401-18	5/27/80	160	12.3
Buffalo	1401-18	6/26/80	161	26.9
Lackawanna	1402-01	7/8/80	162	21.3
Lackawanna	1402-01	8/7/80	159	22.7

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* There were other measured exceedances of the standard at this monitor in 1978, therefore, unlike sites 1401-01 and 1302-01, this station would have been a nonattainment even without the September 11th value, but the margin of nonattainment would have been lower.

Many of the TSP measurements in the Niagara region from 1978-1980 were only slightly above the national annual and secondary 24 hour standard. For these sites, even small reductions in annual and 24 hour average sulfate levels would bring some monitor sites into compliance.

For example, in 1980, there were eight monitors in the Niagara-Frontier region of New York which registered a violation of the annual TSP primary standard (75 ug/m^3). Three of these monitors exceeded the annual TSP standard by 3 ug/m^3 or less. The annual average sulfate value (at the Buffalo site where that figure was calculated) was 10.3 ug/m^3.

Site No.	TSP Annual Value
1401-11	78
1402-02	78
3102-12	76

Subtraction of only a third of the annual sulfate value from the annual TSP value at these three sites would result in TSP value less than the annual TSP standard.

Conversely, some monitors (not listed in Table) were in compliance with the Federal standards, but only by a few micrograms. Therefore, even slight increases in sulfate levels could result in additional noncompliance in the Niagara Frontier. While elimination of the sulfate portion would not, in some cases, result in attainment, it is clear that the sulfate levels inflate the TSP levels and make compliance planning more difficult for New York State authorities and local industries.*

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* The highest 24-hour sulfate readings at Buffalo and Niagara Falls monitoring sites ranged from 37.9 to 56.7 ug/m^3.

Other air quality control regions in western and central New York experienced high sulfate-to-TSP ratios, indicating a significant transported contribution to TSP levels. In the Central Air Quality Control Region at Syracuse, there was one violation of the national annual TSP standard and numerous violations of the primary 24-hour standard at the same monitoring site in 1978. Four other sites registered violation* of the secondary 24-hour standard in 1978 and one such site in 1979. Here, again, high levels of sulfates were measured nearby (8.8 and 8.5 ug/m^3 annual geometric mean, and 35.9 and 21.9 ug/m^3 second highest 24-hour average in 1978 and 1979 respectively). For another Syracuse monitor in 1979, an increase of four micrograms per cubic meter on the second highest 24 hour average would result in an exceedance of the secondary 24 hour standard.** Several other monitors were within a few micrograms of exceeding the primary annual and secondary 24 hour standards during these two years.

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* At one other site the second highest 24 hour value was 152 ug/m^3 and is thus close to being a clear violation of the standard except for the confidence level for the data.

** This would not necessarily result in a nonattainment designation because of the statistical probability range, but certainly a slight reduction or increase in sulfate levels could throw such sites into clear attainment or nonattainment.

In the Southern Tier West Air Quality Region, at Jamestown, annual sulfate levels of 8.7 ug/m^3 and a remarkably high 24-hour average of 43.9 ug/m^3 were measured in 1978. This was the third highest 24 hour sulfate level anywhere in New York. Jamestown is in the New York region which is geographically closest to the high SO_2 emission areas in the Ohio Valley, and Great Lakes region. Since Jamestown has no significant local sulfate sources and is upwind of such sources in New York, the sulfate concentration in Jamestown may be taken to represent the regional transported sulfate burden. Additional discussion of sulfate levels in Jamestown has been presented in Part II of this report and in Attachment D.

In the Hudson Valley Air Quality Control Region, at Albany, violations of the annual and 24-hour standards occurred in 1979. Sulfates at nearby monitors measured between 21% and 23% of the annual TSP value in that year. Three monitors registered violations of the secondary 24-hour standard in 1979 and four violations in 1980.

Sulfate concentrations at all stations in New York City metropolitan area increased in 1978. A high value of 42.3 ug/m^3 was recorded at Yonkers. Between 14% and 20% of the TSP in the New York metropolitan area was made up of sulfates. A study by Wolff et al, discussed in Part II of this report, illustrates the particulate burden which may be transported into New York City.

Throughout west and central New York, there are other areas where sulfates are measured at 20% to 30% of TSP values and where the highest 24 hour averages for sulfates range from 20 to 40 ug/m^3. These measurements of sulfate concentrations are consistent with data reported from the SURE II monitoring network as reported in an April, 1979 study.*

The sulfate-to-TSP ratio has been increasing throughout the State.** Thus, while local control of particulate sources has effectively lowered TSP levels, the transported sulfate burden, over which we have no control, is becoming increasingly important.

Recent analyses of partial data from 1981 confirms the relationship between high sulfate levels and monitored exceedances of the TSP secondary 24-hour standard. Table 4 demonstrates that in many instances where both TSP and sulfate were measured, the sulfate made a substantial contribution and in 6 of 14 cases provided the margin between exceedance and non-exceedance.

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*Mahan, Niemann and Phillips "Characteristics and Origins of Sulfur Dioxide, Total Suspended Particulates, and Sulfates in Western Pennsylvania", EPA Publication No. R-019-EPA-79, prepared for EPA Office of Research and Development, April, 1979, page 58.

**See New York State Department of Environmental Conservation Air Quality Reports Annual 1979 (DAR-80-1) pp. 27, 60, 77, 89, 124, 142, 154; Annual 1978 (DAR-79-1) pp. 29, 66, 82, 96, 113, 133, 153; Annual 1977 (DAR-78-1) pp. 20, 48, 62, 73, 88, 107, 122, 133; Annual 1980 (DAR-81-1 preprint) pp. 69, 95, 112, 139.

TABLE 4. EXCEEDANCES OF 24 HOUR TSP STANDARD AND SAME DAY SULFATE MEASUREMENTS FROM PARTIAL DATA -- 1981*

Station	Site No.	TSP(ug/m^3)	Sulfate(ug/m^3)	Date
Albany	0101-13	169	21.8	1/22
Buffalo	1401-02	157	19.1	2/27
		161	3.5	5/22
Buffalo	1401-11	168	19.1	2/15
		148**	29.4	2/27
		151	25.7	3/29
		165	54.4	4/4
		151	15.3	4/10
		151	19.1	4/16
		178	21.3	5/22
		174	31.7	6/15
Buffalo	1401-18	165	20.2	2/27
		147**	19.6	3/29
		160	13.7	4/10
		167	12.7	5/4
		249	1.8	5/22
Lackawanna	1402-01	182	24.1	2/27
		172	14.8	3/17
		168	16.6	3/29
		164	12.7	4/10
		214	14.6	5/4
		269	18.1	5/22
		218	21.8	6/9
		182	19.4	6/21
Tonawanda	1472-04	149**	16.9	5/22
Rochester	2701-01	168	13.7	2/15
		155	20.8	6/15
Niagara Falls	3102-09	166	5.3	5/22
Niagara Falls	3102-11	200	9.7	2/27
		186	9.7	3/23

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*This table only includes those exceedances for which a sulfate analysis was also performed. Many other exceedances occurred at stations where sulfate analysis was not performed. Such exceedances are not listed on this chart.

**Not actually an exceedance, but close enough to the standard to be questionable by reason of the confidence level for the monitoring data.

B. Many exceedances of the secondary TSP standard are attributable to transported sulfates

To demonstrate the importance of transported sulfate under episodic conditions (i.e. TSP levels above $150ug/m^3$) in Erie County, a linear regression was performed between sulfate concentrations in Buffalo, N.Y. and those in Jamestown, N.Y. for days on which exceedances were recorded in Buffalo (See Attachment D, Figure A10).* This calculation reveals that under episodic conditions there is regional homogeneity in sulfate concentrations, with Jamestown concentrations about 88% of the concentration found in Buffalo.

Meteorological data and trajectory analyses demonstrate that under such episodic conditions, winds in this region are from the southwest, and Jamestown is upwind of Buffalo. Since Jamestown has no local sulfate sources, the levels recorded there represent the imported sulfate load in Erie County. Subtraction of this sulfate concentration from values recorded at monitors showing exceedances in Erie County reveals those exceedances attributable to imported sulfates (Table 5). It should be noted that this is a conservative estimate of the transported particulate burden, as only the sulfate levels are considered and not the many other species of fine

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*The sulfate concentrations at the two locations were linearly correlated with a slope of 0.88 and a correlation coefficient of 0.82.

Table 5. Contribution of Transported Sulfate to TSP 24-Hour Secondary Standard Exceedances in Erie County, N.Y.

Year	Total TSP Exceedances	TSP Exceedances on* Days When Sulfate Was Monitored at Jamestown	Number of Exceedances Attributable to Transported Sulfate	% Exceedances Attributable to Transported Sulfate
1980*	141	71	21	29
1979	122	55	16	29
1978	175	91	25	27
1977	166	99	19	19
1976	248	163	37	23

*Calculations for 1980 based upon 88% of the sulfate levels monitored in Buffalo, rather than Jamestown levels, due to scarcity of monitoring data from Jamestown.

particulates for which sulfates serve as a surrogate.

A similar analysis has been performed for episodic days on which exceedances of the 24-hour TSP Secondary Standard were recorded in Niagara County. Sulfate concentrations reported from the Niagara County site were regressed with the sulfate concentrations on the same date at Jamestown. The regression line had a slope of 0.98 and a coefficient of correlation of 0.86. Thus, as explained above for Erie County, 98% of the sulfate concentrations measured in Jamestown may reasonably be equated to the regional sulfate transport burden in Niagara County. This value has been used to reveal those exceedances in Niagara County, attributable to imported sulfates (Table 6).

Table 6. Contribution of Transported Sulfate to TSP
24-Hour Secondary Standard Exceedances
in Niagara County, N.Y.

Year	Total TSP Exceedances	TSP Exceedances on Days When Sulfate Was Monitored in Jamestown	Number of Exceedances Attributable to Transported Sulfate	% Exceedances Attributable to Transported Sulfate
1980*	19	19	11	58
1979	23	16	4	25
1978	44	42	13	31
1977	32	23	5	22
1976	42	40	20	50

*Calculations for 1980 based upon 68% of the sulfate levels monitored in Buffalo, rather than Jamestown levels, due to scarcity of monitoring data from Jamestown.

C. Description of Nonattainment and PSD Areas in New York

EPA has requested New York to provide a demonstration of the "existence and geographic boundaries of the nonattainment or the PSD areas which are subject to this petition". See Transcript in this docket, of June 18, 1981, Volume 1, page 5.) New York has described its TSP nonattainment problems and listed the areas of the state where the NAAQS is not being met in the preceding pages.* This presentation included an analysis of monitoring data showing the impact of imported sulfates on TSP nonattainment. New York has also described the impact of the imported sulfates on prevention of significant deterioration. (See Part 5(B) of the New York Petitions.) Each of these documents supports New York's position that imported sulfates represent a substantial portion of the ambient TSP loading throughout New York, that the sulfate contribution prevents attainment of the national ambient air quality standards and interferes with New York's efforts to prevent significant deterioration of air quality.

The presence of imported sulfates which derive from midwestern sulfur dioxide emissions have various impacts on total suspended particulate levels in New York, including:

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*See also Part 5 and Attachment F of New York's Petitions and Comments filed with EPA in the SIP revision proceedings listed in Attachment G, and testimony of D. R. Wooley at June 18, 1981 hearing. See also 46 Fed. Reg. 1895(1981).

1. Prevention of attainment of air quality consistent with the NAAQS in some parts of New York;
2. Threatening New York's ability to maintain air quality consistent with NAAQS;
3. Interfering with New York's ability to prevent significant deterioration of air quality in New York;
4. Preventing New York from establishing its own air quality goals, and achieving actual air quality more stringent than the federal requirements.

All areas within the boundaries of the State of New York are affected in one or more of these ways by midwestern So_2 emissions. The following discussion is intended to supplement the documents mentioned in the previous paragraph and to meet EPA's request for more specific designation of the boundaries of the affected areas.

1. Nonattainment Areas

EPA has officially designated* the following areas as nonattainment for the TSP standard pursuant to Section 107(d) of the Clean Air Act:

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*46 Fed. Reg. 8495 (Jan. 21, 1981).

Designated Area	Does Not Meet Primary Standards	Does Not Meet Secondary Standards	Cannot Be Classified
Niagara Frontier AQCR:			
The City of Buffalo (south of I-190; except an area ½ mile inland and parallel to Fuhman Blvd. between I-190 and Tifft St.).	X		
The City of Buffalo (south of Genesee St. except an area ½ mile wide bordering Lake Erie and parallel to Fuhman Blvd. between I-190 and Tifft St.)		X	
The City of Lackawanna	X	X	
The City of Niagara Falls (south of Pine Ave. east of Hyde Park Blvd. and west of I-190).	X		
The City of Niagara Falls		X	
The Town of Niagara		X	
The Village of Blasdell		X	
The Town of Cheektowage (south of Genesee Rod. and west of Union Rd.)		X	
The City of Lockport (north of Rtes. 93 and 31).		X	
Southern Tier West AQCR: The City of Jamestown:		X	
Central AQCR:			
The City of Syracuse		X	
The Village of East Syracuse		X	
The Village of Solvay		X	
Hudson Valley AQCR:			
The City of Albany (east of Rt.32 and south of Rt. 20).		X	
The Town of Catskill (east of Rt. 9W and south of Embought Rd.).		X	
New Jersey-New York-Connecticut Interstate AQCR:			
The Borough of Manhattan			X
The Boroughs of the Bronx, Brooklyn and Queens (south of the Cross Bronx Expressway, west of the Hutchinson River Parkway and Bronx-Whitestone Bridge, west of the Whitestone Expressway, west of the Van Wyck Expressway, north of the Southern Parkway, north of Conduit Blvd., north of Linden Blvd., north of Caton Ave., north of the Ft. Hamilton Paarkway, and north of 39th St.).			X
The Borough of Staten Island (south of I-278, west of Richmond Ave., and north of Arthur Kill Road as far west as Rossville Ave.).		X	

The New York Department of Environmental Conservation (DEC) believes that the boundaries of the nonattainment areas do not actually follow the political boundaries of the designated areas and that nonattainment conditions may exist in a somewhat smaller area than rated by the official designation. For example, figures 4 through 7 represent DEC's approximation of the current nonattainment in areas of Erie and Niagara counties. The isopleths on the maps are extrapolations from 1980 monitoring data. The boundaries of the nonattainment areas may, however, shift from year to year. The official EPA designation _is_, nevertheless, the deciding factor in determining whether new and existing industry must meet the LAER, RACT and/or the other requirements of the nonattainment provisions of the Act (42 U.S.C. 7501 _et seq._).

It is important to note that the areas of nonattainment include several of the largest population centers of the state and that a large percentage of New York's population is affected by these pollutant levels. The true magnitude of human exposure to nonattainment conditions must be judged in light of the population density and not solely on the basis of the nonattainment areas' geographic size.

The analyses in Sections IV A and B above describe more particularly how nonattainment conditions are influenced by imported sulfates.

Figure 4.

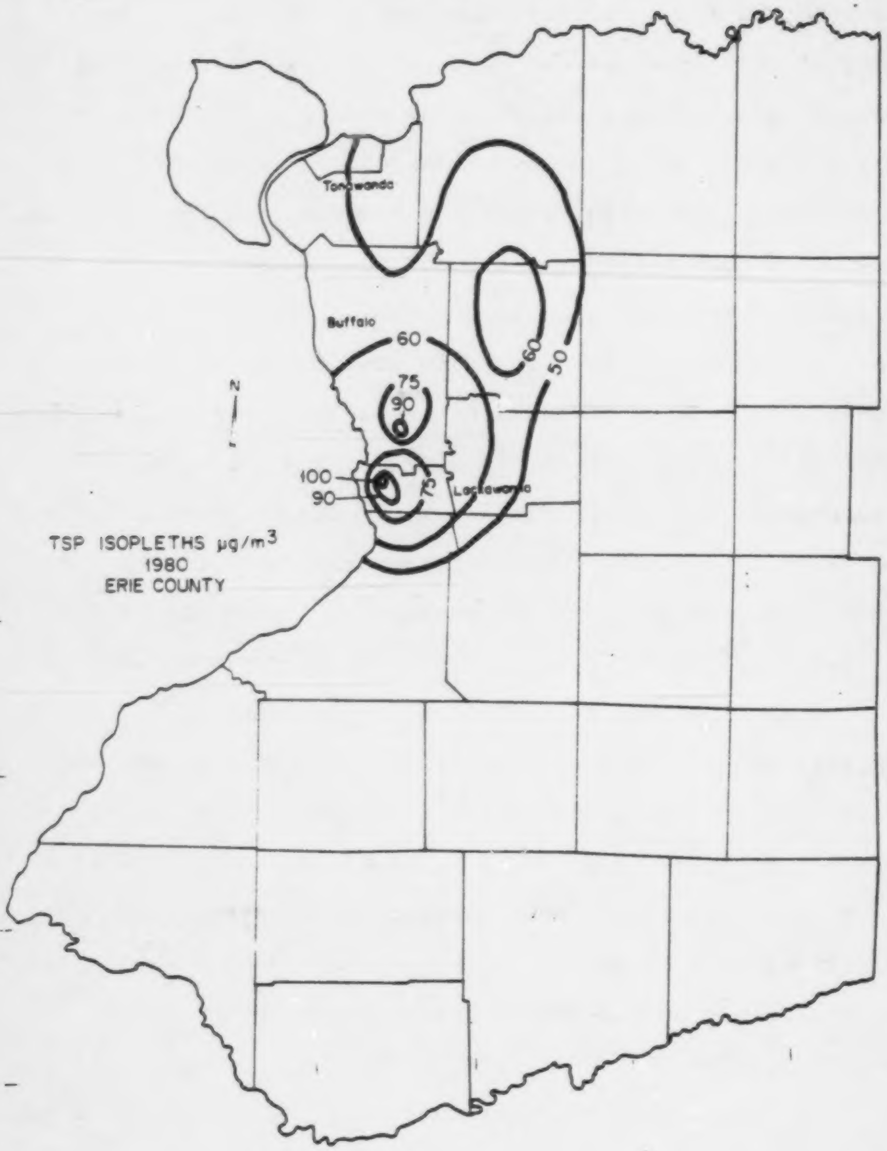
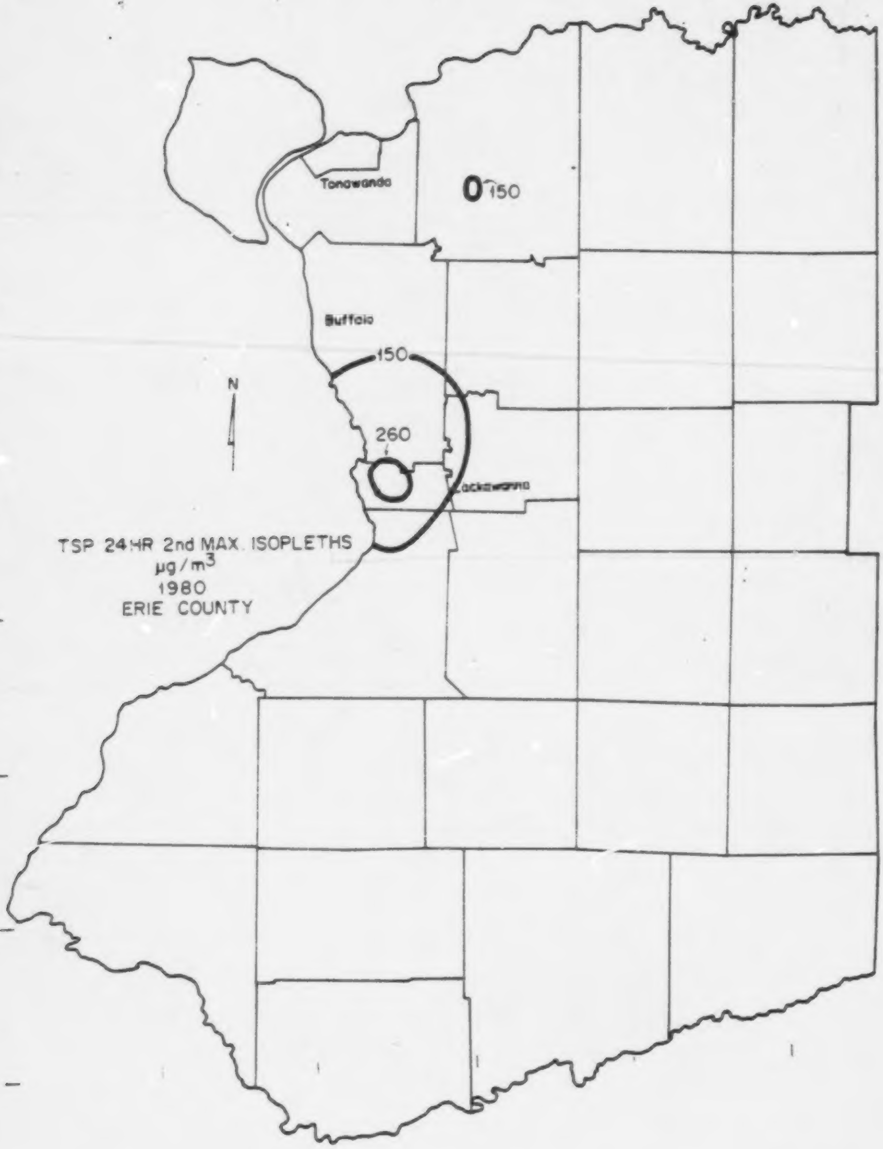

Tonawanda
Buffalo
Lackawanna
N
60
75
90
100
90
75
60
50
TSP ISOPLETHS µg/m³
1980
ERIE COUNTY

Figure 5.


Tonawanda
0
150
Buffalo
150
N
260
Lackawanna

TSP 24HR 2nd MAX. ISOPLETHS
$\mu g/m^3$
1980
ERIE COUNTY

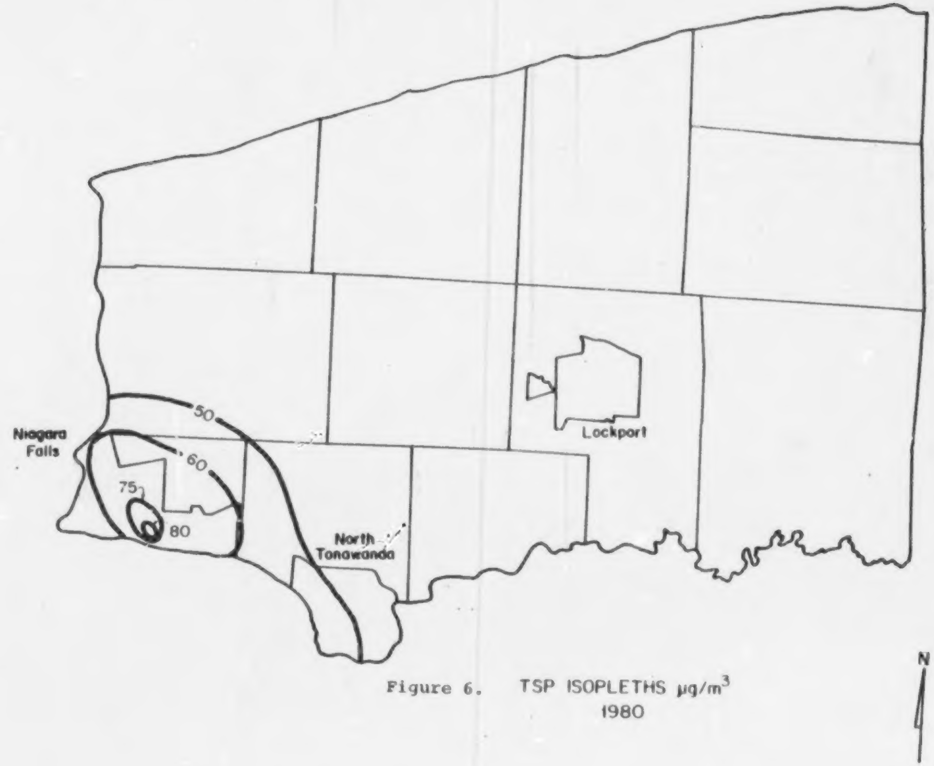

Lockport
North Tonawanda
Niagara Falls
50
60
75
80
N

Figure 6. TSP ISOPLETHS $\mu g/m^3$
1980

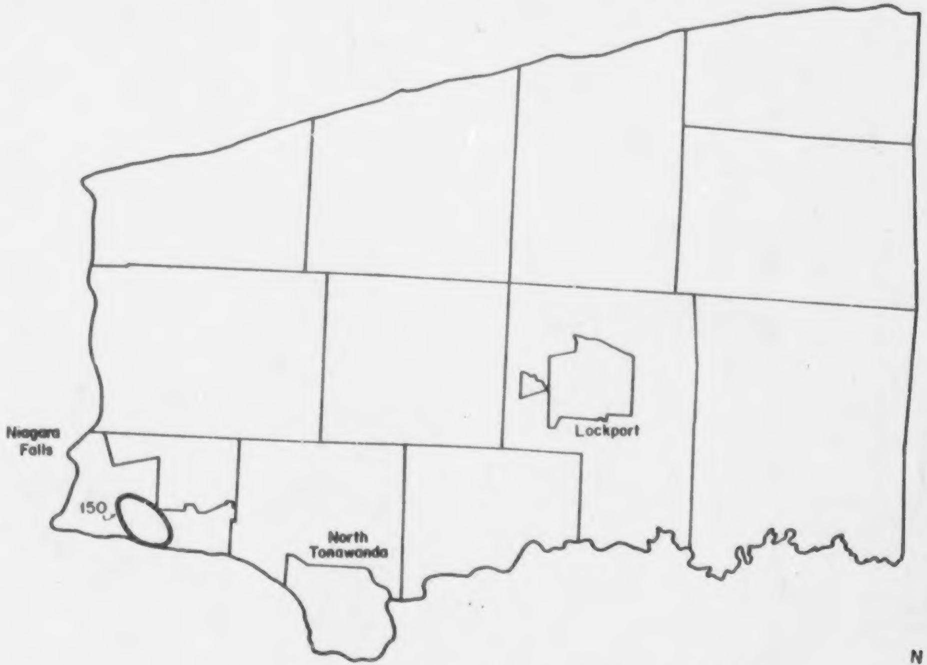

Lockport
North Tonawanda
Niagara Falls
150
N

Figure 7. TSP 24 HR 2nd MAX ISOPLETHS
$\mu g/m^3$
1980

There are many areas of the State where air quality is only slightly better than the national ambient air quality standards for total suspended particulates. Some such areas border the nonattainment areas described above. In the New York City area the boroughs of Manhattan, Bronx, Brooklyn and Queens have been designated by EPA as "cannot be classified" for particulate air quality attainment status (secondary standard).* Any further degradation in this region would indicate reclassification as a nonattainment area.

2. PSD Areas

Aside from the areas in nonattainment, or in very marginal attainment, all other areas in the State are subject to the Prevention of significant Deterioration (PSD) rules. Any increase in SO_2 emissions from existing or new sources in the midwest will contribute to consumption of TSP increments in New York State. Additionally, increases in stack heights for large sources in the Midwest will increase the amount of sulfate transported to New York. EPA's recent proposals regarding these state implementation plans include both stack height increases and actual increases in SO_2 emissions.** EPA has already granted emission increases or stack height increases for large sources in the midwest and without considering long-range PSD impacts.*

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*46 Fed. Reg. 8495.

**See 46 Fed. Reg. 43855 (Sept. 2, 1981), see also Attachment F, "Report of the New York State Attorney General: Pending increases in sulfur dioxide emissions from selected coal-fired electric generating plants in Midwestern states."

D. Description and Status of Non-Attainment Planning in New York

At the June 18, 1981 hearing, members of the EPA panel requested information on the status of New York's plan for achieving the national standard for particulates, in those areas of the State now designated as nonattainment. In the discussion below, New York will describe the status of the plan and summarize the additional emission controls which are being imposed on New York industry to cope with the nonattainment problem.

1. Niagara Frontier Region

On May 25, 1979, the New York State Department of Environmental Conservation submitted a SIP revision to EPA which included a plan for abatement of the TSP pollution to achieve attainment in the Niagara Frontier Region of western New York. This plan was the result of a period of study and planning involving state and local agencies and industry. The plan demonstrates that the primary National Ambient Air Quality Standards for TSP will be achieved by the end of 1982. In order to achieve compliance, the plan mandates additional particulate emission controls beyond those already imposed upon local industry in the Niagara Frontier area. On August 15, 1980, EPA published a proposed conditional approval of the plan. Comments on this proposal were submitted by many parties. The State and EPA have held extensive discussions over the conditions, and the State's progress towards them. The most recent information available is that the Regional Office of EPA has reached a decision on the disposition of the proposed conditional approval and has sent its recommendation on a final rulemaking notice to EPA headquarters. No decision has yet been announced by EPA.

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*See 46 Fed. Reg. 43855 (Sept. 2, 1981), see also Attachment F.

In addition to existing control measures, the following controls will be imposed by New York DEC upon sources of particulates in the Niagara Frontier AQCR:

1. Installation of emission controls at the coke ovens of Donner Hanna Coke and the Bethlehem Steel Corporation Lackawanna Plant, including new particulate emission standards for coke oven battery, coke oven gas desulfurization and visible emission limitations for coke charging and oven leakage (pursuant to consent order with Bethlehem Steel), and revisions to 6NYCRR Part 216.

2. Installation of additional fixed or movable hoods and high efficiency air-cleaning devices on basic oxygen furnaces at Republic Steel and Bethlehem Steel; these will collect emissions during tapping, lancing and fluxing operations to be passed through a best available control technology device to clean the air emissions.

3. Installation of high efficiency air cleaning devices to control emissions from blast furnaces' iron notch and trough at Bethlehem Steel, Hanna Furnace and Republic Steel.

This will involve the installation of a highly efficient air cleaning device and collection of emissions through the installation of local control exhaust hoods over the iron notch and trough.

4. Development of a fugitive dust control program by industries and municipalitiesfor paved and unpaved roads, parking lots, stockpiles, material handling activities, and open transport of loose substances.

In addition to these requirements, specified by DEC, the conditional approval expected to be issued by the Environmental Protection Agency will impose the following controls on stationary sources in the Niagara Frontier area:

1. Controls on fugitive emissions from coke oven battery's pushing and transport operations and shed exhausts;

2. Controls to establish a minimum water quality standard for water used in quenching of coke (including specific test procedures);

3. Controls on cast house fugitive emissions for blast furnaces;

4. Devices for the capture and cleaning of all fugitive emissions from basic oxygen furnaces including charging operations;

5. Additional emission controls for sinter plant windbox and emissions;

6. Additional controls for automatic scarfing machine emissions.

As demonstrated by the draft final rulemaking notice prepared by EPA Region II, New York D.E.C. has already complied with several of the additional conditions which EPA has set forth for control of TSP sources in the Niagara Frontier area.

The attainment plan discussed above does not, however, provide for attainment of the secondary National Ambient Air Quality Standards for particulates. The plan states that an analysis of the application of all known reasonably available control technologies indicates that their application would not enable attainment of the secondary standard. The plan, therefore, requested an extension of time to prepare a separate secondary plan. In the Federal Register notice announcing the proposed conditional approval of the Niagara Frontier Plan, EPA stated its agreement with New York's position that the secondary standard could not be attained by the use of reasonably available control technology on traditional stationary sources. For this reason EPA proposed to approve the request for an extension of time for the filing of a secondary nonattainment plan.*

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*EPA proposed to approve an 18-month extension of time for the filing of this plan. The New York Department of Environmental Conservation believes that this 18-month period will begin to run on the date of the final publication of the "Conditional Approval". Although EPA disagrees with this interpretation, it has stated it would not enforce its interpretation of the law by the imposition of growth restrictions under §110(a)(2)(i). New York's preexisting attainment plan for the secondary standards was published in July, 1973 by the New York Department of Environmental Conservation.

2. Other New York Nonattainment Areas

New York has been granted an extension to carry out a study and prepare a nonattainment plan for the Syracuse area.* Analysis shows that the use of RACT will not result in the attainment of the secondary standard in part of Syracuse. A nonattainment plan for the Capitol district (including nonattainment areas in Albany, Schenectady, and Catskill) was prepared and submitted to EPA in 1978 and approved by EPA in February 1979.**

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*See New York State Air Quality Implementation Plan, Syracuse Area, addenda and errata, March 1979, p. 12.

**See New York State Air Quality Implementation Plan, Capitol District and Town of Catskill, pp. 4-1 and 4-5.

E. Compliance status of particulate sources in New York.

At the June 18, 1981 hearing, an EPA representative requested information as to the compliance status of particulate sources in New York. In response to this question, New York provides the following information.

The particulate sources in nonattainment areas are generally in compliance with the state implementation plan. Exceptions and their status are noted in the following table. Each item represents non-compliance with the most recent nonattainment plan, which is now awaiting final EPA approval.

Facility	County	Compliance Schedule	Amount Over Allowable
Airco Speer	Niagara	No	0.2 T/Yr.
Donner Hanna Coke	Erie	Yes	244 T/Yr.
Hanna Furnace	Erie	Yes	56 T/yr.
Republic Steel*	Erie	No	86 T/yr.
Bethlehem Steel	Erie	Yes	1948 T/yr.

Installation of additional controls, as required by the new nonattainment plan has begun at all of the above plants except Airco Speer. This information was obtained through the compliance data system compiled and operated by the New York Department of Environmental Conservation, Division of Air Resources.

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*DEC reports that Republic Steel is unwilling to enter into a compliance schedule agreement with the State until the SIP is approved by EPA.

The New York State nonattainment plan demonstrates that reductions in emissions of particulates are required beyond the amount which can be attained solely through compliance with the existing State Implementation Plan. The rate of compliance with particulate emission limits in New York is very high, yet full compliance would not result in attainment of the National Ambient Air Quality Standards in nonattainment areas in New York.

F. Midwestern Power Plants Are the Primary Sources of Sulfur Dioxide Emissions in the Eastern United States

The midwestern states contribute a high percentage of the total U.S. sulfur dioxide emissions. For example, in 1978 the States of Illinois, Indiana, Michigan, Ohio, Tennessee, Kentucky and West Virginia emitted approximately 11.3 million tons per year (Table 7). In comparison, combined emissions from the states of New York, New Jersey and all New England states totaled only approximately 2 million tons per year. Emissions from the state of Ohio were almost three times higher than total New York SO_2 emissions; and, the Ohio emissions exceeded by 50% the combined total of the states of New York, New Jersey and all New England states.

Emissions from utility sources contribute a high percentage to the total national emissions for sulfur dioxide. Older power plants are of primary concern, because they may emit five to seven times the amount of sulfur dioxide permitted from new sources.* Electric utilities produce 65% of the sulfur dioxide emitted nationally(Table 8).

The magnitude of midwestern utility emissions of SO_2 is demonstrated by the fact that the utility emissions from these states represent nearly 43% of the national total for utility emissionsof SO_2. Their emissions represent approximately 74% of the total SO_2 emissions from all sources in these states.

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* NCAQ, op. cit., p. 3.9-12.

Table 7.

1978 SO_2 AND NO_x EMISSIONS BY STATE (10^3tons)

State	SO_2	NO_x
Alabama	762.1	473.0
Arkansas	121.6	217.9
Connecticut	112.0	183.0
Delaware	188.2	70.6
District of Columbia	17.6	33.5
Florida	685.9	777.4
Georgia	707.0	548.8
Illinois	1747.2	1129.9
Indiana	1848.2	600.6
Iowa	385.0	321.0
Kentucky	1330.0	563.0
Louisiana	359.0	1593.7
Maine	66.0	76.7
Maryland	357.3	313.9
Massachusetts	402.2	364.3
Michigan	1117.8	843.1
Minnesota	379.0	399.6
Mississippi	264.3	272.8
Missouri	1307.7	563.0
New Hampshire	67.8	66.9
New Jersey	323.7	494.4
New York	1041.1	908.9
North Carolina	562.3	591.0
Ohio	3115.3	1277.1
Pennsylvania	1900.0	1120.7
Rhode Island	19.7	42.4
South Carolina	288.6	300.2
Tennessee	1162.8	592.9
Texas	1244.8	3309.5
Vermont	-	-
Virginia	359.9	435.2
West Virginia	1049.5	462.4
Wisconsin	663.6	473.2
TOTAL	23957.2	19420.6
	or 21.73 million tonnes	17.62 million tonnes

Source: U.S. Memorandum of Intent, Emissions, Costs and Engineering Assessment Interim Report, Feb. 1981.

Table 8.

CURRENT (1978) EMISSIONS OF SO_2 AND NO_x - U.S. (10^6 tonnes)

Category	SO_2 (% of total)		NO_x (% of total)	
Utilities	17.6	(65%)	7.2	(31%)
Industrial Boilers	3.2	(12%)	4.9	(21%)
Industrial Processes	4.1	(15%)	0.8	(3.5%)
Transportation	0.8	(3%)	9.4	(40%)
Residential/Commercial	1.3	(5%)	0.8	(3.5%)
Solid Waste Disposal	0.0	(0%)	0.1	(0.5%)
Miscellaneous	0.0	(0%)	0.1	(0.5%)
Total	27.0	(100%)	23.3	(100%)

Source: U.S. Memorandum of Intent, Emissions, Costs and Engineering Assessment Interim Report, February 1981, page 14.

The nineteen power plants named in the May 1, 1981 Federal Register notice establishing this docket contribute a significant percentage of these emissions. For example, in 1979 these plants emitted a combined total of 2,091,300 metric tons of SO_2, or 27% of the total utility emissions from these states. These plants are located in regions of very high sulfur dioxide emission density. Fig. 8 shows that the Ohio River Valley and Great Lakes region contain the largest concentrations of sulfur dioxide sources in the nation.

The Petitions and Comments which New York has filed with EPA focused on these plants because they have been the subjects of SIP revision proceedings pursuant to §110(a) of the Clean Air Act. (See Attachment G for full list of §110(a) proceedings in which New York State has participated.) The Petitions and Comments in these proceedings note that an increase of 1.5 million tons annually in allowable SO_2 emissions would result if EPA granted each of the emission limit relaxations requested by the states and utilities.*

Since New York's first filingin January 1981, EPA has approved emission limit increases at some plants. These are the Cardinal, Bayshore and Cobb plants. EPA has proposed to increase allowable emissions at the Niles and Miami Fort plants: see

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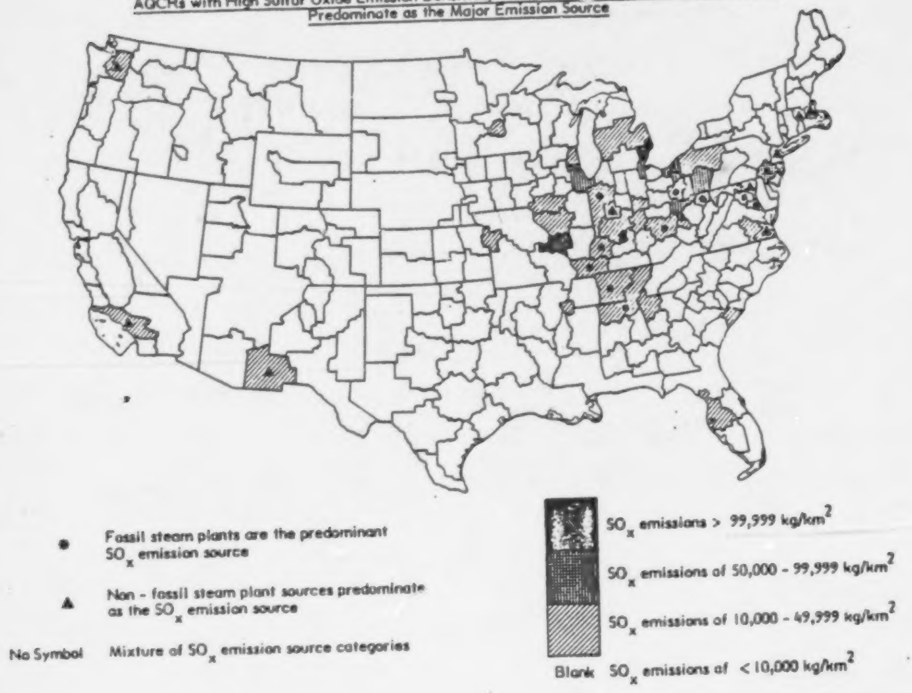
*Such action would have increased actual emissions by approximately 511,000 million tons annually. Report of the New York State Attorney General: Pending Increases in SO_2 Emissions From Selected Coal Fired Electric Plants in Midwest States (Attachment F); Report of the National Commission on Air Quality at 3.9-25. EPA had already approved increases in allowable emissions for 9 other Midwest plants totaling 818,000 tons.

Figure 8.

AQCRs with High Sulfur Oxide Emission Densities, Where Fossil Steam Plants Do or Do Not Predominate as the Major Emission Source


● Fossil steam plants are the predominant SO_x emission source
▲ Non - fossil steam plant sources predominate as the SO_x emission source
No Symbol Mixture of SO_x emission source categories
SO_x emissions > 99,999 kg/km^2
SO_x emissions of 50,000 - 99,999 kg/km^2
SO_x emissions of 10,000 - 49,999 kg/km^2
Blank SO_x emissions of < 10,000 kg/km^2

From: Gage, S.J., L.F. Smith, P.M. Cukor and B.L. Nieman. "Long-range transport of SO_x/MSO_4 from the U.S. EPA/Teknekron integrated technology assessment of electric utility energy systems." Paper prepared for presentation at the International Symposium on Sulfur in the Atmosphere, Dubrovnik, Jugoslavia, September, 1977.

New York's Petition and Comments dated March 26, 1981. Furthermore, EPA has granted long delays in the compliance deadlines for several plants; these are the Cardinal, Conesville, Muskingum Plants. 45 Fed. Reg. 73927 (1980). EPA has also suspended the more restrictive limits which were due to come into effect for two of the Cleveland Electric Illuminating plants (Avon Lake and East Lake, 45 Fed. Reg. 42279, June 24, 1981; see also New York's Petition and Comments filed March 26, 1981).

These plants are not, of course, the only pollution sources of concern to New York. It is not difficult to identify the other large producers of sulfur dioxide in the midwest region. For example, the Canadian Province of Ontario has prepared a list of the top 50 coal-fired power plant emission sources in the eastern United States and has ranked them according to total emissions and by restrictiveness of emission limitations
(Table 9).

In its earlier testimony in this proceeding, New York submitted a list of 59 power plants, which New York believes are the largest and most poorly controlled plants in the seven midwest states of Ohio, West Virginia, Indiana, Illinois, Michigan, Tennessee and Kentucky.* These plants were chosen on the basis of the following criteria: they are (1) electric generating power plants, (2) with generating capacity of at least 80 megawatts (3) whose annual coal usage is greater than 100,000 tons (1979), and (4) with emission limits or actual

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*See testimony of D. R. Wooley at June 18, 1981 hearing, Table K.

Table 9.

TOP 50 COAL-FIRED POWER PLANTS RANKED ACCORDING TO TOTAL SO_2 EMISSION IN 1979

RANK	PLANT	STATE	COUNTRY	ESTIMATED SO_2 EMISSION THOUSANDS OF METRIC TONS/YEAR	
1	PARADISE	KENTUCKY	U.S.A.	372.5	
2	MUSKINGUM	OHIO	U.S.A.	340.2	
3	GAVIN	OHIO	U.S.A.	339.5	
4	CUMBERLAND	TENNESSEE	U.S.A.	289.7	
5	MONROE	MICHIGAN	U.S.A.	264.9	
6	CLIFTY CREEK	INDIANA	U.S.A.	263.7	
7	GIBSON	INDIANA	U.S.A.	261.1	
8	BALDWIN	ILLINOIS	U.S.A.	257.9	
9	LABADIE	MISSOURI	U.S.A.	224.0	
10	KYGER CREEK	OHIO	U.S.A.	205.5	
11	BOWEN	GEORGIA	U.S.A.	202.6	
12	CONESVILLE	OHIO	U.S.A.	186.8	
13	MITCHELL	WEST VIRGINIA	U.S.A.	186.2	
14	HATFIELDS	PENNSYLVANIA	U.S.A.	167.3	
15	NEW MADRID	MISSOURI	U.S.A.	164.0	
16	SAMMIS	OHIO	U.S.A.	160.7	
17	LAMBTON	ONTARIO	CANADA	160.2	
18	WANSLEY	GEORGIA	U.S.A.	159.7	
19	HOMER CITY	PENNSYLVANIA	U.S.A.	159.1	
20	JOHNSONVILLE	TENNESSEE	U.S.A.	157.9	
21	NANTICOKE	ONTARIO	CANADA	155.0	
22	GASTON EC	ALABAMA	U.S.A.	154.8	
23	MONTROSE	MISSOURI	U.S.A.	147.1	
24	HARRISON	WEST VIRGINIA	U.S.A.	142.8	
25	BRUNNER ISL.	PENNSYLVANIA	U.S.A.	142.0	— TANNERS CREEK *
26	COFFEEN	ILLINOIS	U.S.A.	141.8	
27	CARDINAL	OHIO	U.S.A.	140.8	— KINGSTON
28	EASTLAKE	OHIO	U.S.A.	137.4	
29	KAMMER	WEST VIRGINIA	U.S.A.	136.8	
30	KINCAID	ILLINOIS	U.S.A.	136.3	
31	KEYSTONE	PENNSYLVANIA	U.S.A.	127.2	
32	STUART J.M.	OHIO	U.S.A.	125.6	
33	CAYUGA	INDIANA	U.S.A.	121.7	— WARRICK
34	SHAWNEE	KENTUCKY	U.S.A.	111.0	
35	GALLATIN	TENNESSEE	U.S.A.	110.6	
36	MONTOUR	PENNSYLVANIA	U.S.A.	109.4	
37	BIG BEND	FLORIDA	U.S.A.	109.2	
38	CONEMAUGH	PENNSYLVANIA	U.S.A.	108.9	
39	WIDOWS CREEK	ALABAMA	U.S.A.	106.0	
40	AMOS	WEST VIRGINIA	U.S.A.	105.2	
41	THOMAS [illegible]L	MISSOURI	U.S.A.	104.9	
42	JOPPA STEAM	ILLINOIS	U.S.A.	104.9	
43	MT. STORM	WEST VIRGINIA	U.S.A.	102.5	
44	PETERSBURG	INDIANA	U.S.A.	100.7	— MICHIGAN CITY
45	BECKJORD	OHIO	U.S.A.	99.7	
46	AVON LAKE	OHIO	U.S.A.	98.0	
47	FORT MARTIN	WEST VIRGINIA	U.S.A.	94.6	
48	MIAMI FORT	OHIO	U.S.A.	94.2	
49	LAKEVIEW	ONTARIO	CANADA	91.4	
50	YATES	GEORGIA	U.S.A.	88.8	

POWER PLANTS WERE CONSIDERED FROM ONTARIO AND 32 EASTERN U.S. STATES. THE STATISTICS ARE FROM ONTARIO HYDRO AND THE U.S. DEPARTMENT OF ENERGY; THE ANALYSIS WAS PERFORMED BY THE ONTARIO MINISTRY OF ENVIRONMENT, AIR RESOURCES BRANCH.

From: Province of Ontario, A Submission to the U.S. EPA Opposing Relaxation of SO_2 emission limits in State Implementation Plans and Urging Enforcement, March 27, 1981, at pages 17-18

* The plant names in the extreme right portion of the page would achieve this rank if EPA were to grant proposed increases in emission limitations, and if the plants were to emit pollutants up to the relaxed limit.

emissions are near or above 4 lb/10^6BTU. Although there may be other sources in these and in other states which could be and should be better controlled, this list provides a guide as to where initial emission control efforts should be directed. The plants emitting at the highest rates and using lowest cost and quality fuels should be the first to be required to reduce emissions in any abatement scheme.

Substantial reductions in SO_2 emissions can be achieved in the midwestern United States. It has been estimated that 2.5 to 3.3 million tons of sulfur dioxide per year could be eliminated by the imposition of sulfur dioxide emission limits similar to those in effect in Pennsylvania and western New York (4 pounds SO_2 per million BTU).* There are at least 68 plants located primarily in Illinois, Indiana, Kentucky, Ohio and West Virginia which are currently emitting at a higher rate than this.**

SO_2 emission rates in New York state are much lower than in midwestern states. In New York there are ten coal-fired electric generating plants and thirty-one oil-fired plants. Table 10 indicates that the sulfur content of coal received at these plants is substantially lower than that utilized at the midwestern plants. Only three of the eight New York plants burn coal with a SO_2 content greater than 3.5 lbSO_2/10^6 BTU.

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*See U.S. DOE, Cost and Quality of Fuels for Electric Utility Plants 1979 (June 1980), at pages 81-90. For most plants in New York the limits are much lower. The 4 lb. limit is only in effect for a few plants.

**To Breathe Clean Air--Report of the National Commission on Air Quality, Washington, D.C., March 1981.

Table 10.

Coal Fired Electric Plants - New York State

Plant Name	Company Name	1979 Delivered Coal Fired Qual. $lbSO_2/10^6$ BTU	Plant Size*	Plant Location
Samuel A. Carlson	Jamestown Bd. of Pub. Wks.	3.612		
Goudey	New York State Elec. & Gas	3.264	103	Broome Co., New York
Greenridge	New York State Elec. & Gas	3.416	178	Yates Co., New York
Hickling	New York State Elec. & Gas	1.806	70	Steuben Co., New York
Jennison	New York State Elec. & Gas	1.58	60	Chenango Co., New York
Milliken	New York State Elec. & Gas	3.034	270	Tompkins Co., New York
Huntley	Niagara Mohawk Power	2.388	878	Erie Co., New York
Dunkirk	Niagara Mohawk Power	3.380	628	Chautauqua Co., New York
Rochester 3 (Beebee)	Rochester Gas & Electric	4.24	196.2	Monroe Co., New York
Rochester 7 (Russell)	Rochester Gas & Electric	3.678	252	Monroe Co., New York

*Megawatts.

Moreover, the New York plants are small in size and, therefore, use less coal than do many of the huge plants operating in the Ohio River Basin. Of New York oil-fired plants, 24 used oil in 1979 having a sulfur content of only 0.34% or less, with many of these burning fuel with less than 0.2% sulfur. At the remaining seven plants, fuel ranged from 0.96% to 2.39% sulfur (Table 11). In the case of each of those seven plants, sulfur emission is less than 1.4 $lbSO_2/10^6$ BTU.

The coal-fired electric power plants in the midwestern states of Ohio, West Virginia, Indiana, Illinois, Michigan, Kentucky and Tennessee emit sulfur dioxide in quantities which dwarf the emissions of New York and the New England states.

Sources in these states should therefore be the subject of initial abatement strategies since the largest sources and the most uncontrolled sources of sulfur dioxide emissions are located in these states.

TABLE 11 -- SO_2 Emissions from Selected Oil Fired Power Plants, 1979

Plant Name	% Sulfur	$lbSO_2/10^6BTU$	Total SO_2 Emissions	Company Name
Danskamer	.96	.55	8424	Central Hudson Gas & Electric
Rosedon	1.93	1.10	64654	" "
North Port	2.03	1.17	84102	Long Island Lighting Co.
Port Jefferson	2.39	1.38	31904	" " " "
Oswego	2.34	1.35	49876	Niagara Mohawk Power
Albany	2.00	1.15	22722	" "
Rochester 3	1.83	1.06	5098	Rochester Gas & Electric
		TOTAL	266,790	

TESTIMONY OF ROBERT M. FRIEDMAN
OFFICE OF TECHNOLOGY ASSESSMENT

My name is Robert Friedman. I am a senior analyst with the Congressional Office of Technology Assessment, and currently direct the OTA study on the Impacts of Atmospheric Alterations. The assessment was requested by this Committee and the House Committee on Energy and Commerce. Our study concentrates on a broad range of issues associated with the potential impacts of controlling or not controlling long-range transport air pollutants. Our study is still underway and therefore the information that I will present this morning has not been reviewed by either our advisory panel or the Technology Assessment Board.

This morning, Mr. Chairman, I would like to discuss the implications of two bills framed to control acid deposition — S. 1706 as introduced by Senator Mitchell, and S. 1709 as introduced by Senator Moynihan. Both bills require sulfur dioxide emission reductions in an eastern region comprised of the 31 states bordering on or east of the Mississippi River, and the District of Columbia.

I would like to focus my remarks on three topics:

- An inventory of the sulfur dioxide emissions on a state-by-state basis in this eastern region.
- Estimates of the required emission reductions for each state as specified by S. 1706 and S. 1709.
- Model-based estimates of the cost of emissions reductions specified by these two bills. These cost figures assume that reductions are accomplished solely by decreasing utility emissions of sulfur dioxide, even though both these bills allow emission reductions to be achieved in other ways.

I. Sulfur Dioxide Emissions Inventory.

For 1980, sulfur dioxide emissions in the 31 eastern state region were estimated to be approximately 22.5 million tons. Utility sulfur dioxide emissions were estimated to be about 16 million tons, or about 70% of the total. Non-utility emissions (including industrial combustion, residential and commercial combustion, and industrial process emissions from refineries, iron and steel producers, and smelters, among others) comprised the remaining 6.5 million tons or 30% of the total.

Table 1 presents 1980 sulfur dioxide emissions, and the percent contributed by utilities, by state. A more detailed emissions inventory is presented in the appendix.

Because of the design of both the Mitchell and Moynihan bills, calculating state-level emissions reductions specified by each bill requires the use of a utility inventory that accounts for emissions on a plant-by-plant basis. The utility emissions inventory we have used, developed by Pechan and Associates, Inc. for the Environmental Protection Agency, includes estimated emissions from all major fossil-fuel electric generating plants in the United States.[1]

While we cannot assess the absolute accuracy of this inventory, we consider that the procedures used to develop it result in the best emission data available for 1980, the year specified in the legislation.

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[1] This inventory includes emissions estimates from 1,830 electric generating plants based on fuel used, fuel type, sulfur content of the fuel, and whether scrubbers are used. Comparing our inventory estimates for the 77 largest emitting plants to the numbers reported for those plants by their operating utilities, the inventory we are using is, on average, about 10% lower than the utility-reported estimates. As compared to emission estimates prepared by another EPA contractor (Teknekron Research, Inc.), using slightly different procedures, the two inventories agree to within 1% nationwide, with state-by-state variations averaging 20%.

II. Emissions Reductions Specified by the Bills.

1. S. 1706, the "Mitchell Bill".

The Mitchell bill requires that the amount of sulfur dioxide and nitrogen oxides emitted from the eastern 31 states and D.C. not exceed the amount of each of these pollutants emitted from the region as of January 1, 1981. Moreover, the bill requires that within 10 years of enactment, sulfur dioxide emissions from the eastern region be reduced to 10 million tons less than the actual amounts of sulfur dioxide emitted during 1980. This is a sulfur dioxide emissions reduction from about 22.5 million to 12.5 million tons per year, or about 45% of 1980 emissions for the region.

S. 1706 also specifies the amount by which each state must reduce its sulfur dioxide emissions. This reduction is defined as a fraction of the 10 million ton target. The fraction is stated entirely in terms of utility emissions.[2]

Table 2 presents the sulfur dioxide emission reduction by state, as allocated by S. 1706. The first column shows 1980 emissions by state, and the second column displays the reductions in 1980 sulfur dioxide emissions required by the bill. However, it is important to note that under current laws and regulations embodied in State Implementation Plans (SIPs), some states are presently required to decrease the sulfur dioxide emissions. In fact, approximately 1.5 of the 10 million ton reduction specified by S. 1706 is already required under existing SIPs. Column 3 shows the reductions in emissions required beyond those needed to comply with the provisions of existing laws and regulations.

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[2] As we interpret the wording of the bill, the amount by which a state must reduce its emissions is determined by the following formula. Calculate the difference between a state's current emissions level and the emissions that would result if no electric-generating plant in that state emitted sulfur dioxide at a rate greater than 1.2 pounds per million Btus. (Though the bill states that the reductions be calculated on the basis of 1.2 pounds of sulfur per million Btus, we have assumed it to mean 1.2 pounds of sulfur dioxide per million Btus.) Repeat this calculation for the region as a whole. The state's proportion of the total regional difference, multiplied by 10 million tons, is the amount of sulfur dioxide emissions that must be reduced in that particular state. Detailed, state-by-state calculations are included in the appendix.

Under the bill, the mandated decreases in state sulfur dioxide emissions can be achieved in different ways. The reduction can come from any source -- utility or non-utility -- within the state, from another state if an agreement can be reached, or by reducing two tons of nitrogen oxide emissions for each ton of sulfur dioxide.

2. S. 1709, the "Moynihan Bill".

The Moynihan bill is similar to the Mitchell bill in that it specifies the same eastern state region and allows states the same flexibility in implementing reductions. However, the Moynihan bill differs from the Mitchell bill in that it does not specify sulfur dioxide emissions reduction by tonnage. Rather, the emissions reduction target is a percentage of actual emissions from only the largest electric-generating plants — which we estimate to include about 60 plants located in about half the states in the 31 state region.[3]

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[3] This bill specifies emission reductions in the amount equal to 85% of current sulfur dioxide emissions from those electric generating plants which emitted in excess of 50,000 tons of sulfur dioxide in 1980, at a rate greater than 3 pounds of sulfur dioxide per million Btus. The required emission reductions are in excess of those necessary to reach SIP compliance. No state is required to reduce utility emissions, calculated after SIP compliance, by more than 50% (if the state average sulfur dioxide emission rate is less than or equal to 2 pounds per million Btus), or more than 75% (if the state average emission rate is greater than 2 pounds per million Btus.)

By our analysis, the sulfur dioxide emission reductions specified by the bill are about 6.7 million tons.[4] As mentioned previously, a 1.5 million ton reduction in sulfur dioxide emissions is already required by existing SIPs. Therefore, the total decrease in emissions achieved under the bill is about 8.2 million tons of sulfur dioxide.

Table 3 illustrates the required sulfur dioxide emission reductions, by state, for S. 1709. The first column shows 1980 emissions and the second column displays the reductions in 1980 sulfur dioxide emissions required by the bill.

3. Comparison of the two bills.

The Mitchell bill and the Moynihan bill have several aspects in common:

1. Though both bills calculate emission reductions by considering electric utilties only, they allow the states to obtain emission reductions a) from any source within the state, b) by obtaining emission reductions from other states, and c) by substituting nitrogen oxide emission reductions for sulfur dioxide.

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[4] Using the inventory described earlier, we find that the Moynihan bill applies to 58 utility plants in 16 of the states in the 31 state region. Only one state would be likely to choose the "maximum emissions reduction" clause of 50 or 75% of base year total utility emissions, rather than reduce 85% of emissions from only those plants emitting in excess of 50,000 tons SO_2 at a rate greater than 3 lbs. per million Btu. However, given the nature of our data base, our analysis of the Moynihan bill is approximate. In tabulating emissions according to this bill, units which are required to meet New Source Performance Standards (NSPS) are not included. Our present analysis cannot readily accommodate this provision. Accordingly, two plants might be added to the current list of 58 subject to the 85% reduction requirement, and one or two may be deleted, when the NSPS provision is included. In addition, six plants may be calculated to have lower emissions due to the deletion of NSPS units from the inventory. We feel that the emissions reductions would probably vary by no more than 100,000 tons, or less than 1% for the entire region, but the effects on individual states might be more significant. Detailed calculations are included in the appendix.

2. Both bills specify state-level emission reductions by a formula based on the rate of sulfur dioxide emissions. Therefore, states with electric-generating plants emitting at the highest rates will receive the largest share of emission reductions.

3. Calculating reductions specified by both bills with the accuracy required for regulation is a difficult task, and thus it may present implementation problems.

Some of the important differences between the Mitchell bill and Moynihan bill are:

1. Including all other state and federal laws regarding emissions reductions, the Mitchell bill results in about a 10 million ton reduction, and the Moynihan bill, about an 8 million ton reduction from 1980 emission levels.

2. The Mitchell bill allocates emissions reductions to almost all the states in the Eastern U.S.; the Moynihan bill, to about half the eastern states.

Determining the reductions specified by the Mitchell bill requires a very large quantity of historical data, but the reduction formula is relatively insensitive to small changes in the inventories. The Moynihan bill requires much less data, but is much more sensitive to small changes in calculated, historical emissions.

Table 4 presents a comparison of the emission reductions required by the two bills. The emissions percentages specified in each case are of 1980 sulfur dioxide emissions, after complying with both current state and federal laws and the requirements of the bills.

Under the Mitchell bill, sulfur dioxide emissions are reduced from 22.5 million tons per year to about 12.5 million tons, or by 45%. The Moynihan bill reduces emissions to 14.3 million tons, which is a 36% reduction in eastern sulfur dioxide emissions. Detailed calculations of the emissions reductions required by the two bills are present in the appendix.

III. Regional Costs.

Rather than making single estimates of the costs of the Mitchell and Moynihan bills, we have developed a range of estimates corresponding to different assumptions as to how the emission reductions might be accomplished at the state level.

We estimate the reductions specified by the Mitchell bill will range from $3.3 to $4.1 billion per year. The costs associated with the Moynihan bill range from an estimated $2.2 to $2.6 billion per year. These costs are first year, annualized costs.

It should be noted that these estimates do not include the cost for emissions reductions required under current law. To facilitate comparison of the cost estimates, I have prepared a graph (Figure 1) of our cost analyses. The two circles represent upper and lower estimates of costs under the Mitchell bill and the squares represent the same for the Moynihan bill. To derive our lower estimates, displayed as the lower square and circle, we have performed the analysis assuming that each state will choose the most cost-effective way of meeting the required emission reductions. This might occur by some intra-state trading mechanism or by a state is requiring emissions reductions from those plants that can reduce emissions least-expensively. However, no interstate trading occurs. To derive our upper estimates, displayed as the upper square and circle, each state would achieve required reductions by imposing uniform emission ceilings on utilities. A state regulatory agency might calculate that, in order to meet its emissions reductions, no utility can emit sulfur dioxide at a rate greater than, for example, 1.5 pounds per million Btus. All plants emitting in excess of this rate would be required to reduce emissions to meet this level.

For comparison, we have also provided an analysis of a scenario under which emissions reductions would be accomplished by choosing the least-cost strategy of achieving reductions in the entire 31-state region through interstate trading. This is represented by the curve on the figure. This strategy assumes a "perfect market" with total freedom to trade emissions across the entire region.

One can see from the figure that if this least-cost regional approach were possible, the emission reduction targets of the Mitchell and Moynihan bills could be achieved at a cost of $3.1 and $1.7 billion per year, respectively. This is compared to our lower cost estimates of $3.3 and $2.2 billion per year, respectively, under which interstate trading is not considered.

To put these cost estimates in perspective, the Congressional Budget Office has estimated the total cost for utility air pollution control in the United States in 1980 to be about $5.8 billion dollars. CBO estimates that this corresponds to about 0.255 cents per kilowatt-hour, or about 4 percent of an average residential electric bill. These costs vary regionally, of course, between almost no cost in the Pacific Northwest and 0.5 cents per kilowatt-hour in New England.[5]

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[5] "The Utility Industry and the Clean Air Act." Staff Working Paper, Natural Resources and Commerce Division, Congressional Budget Office, June 24, 1981.

The cost estimates generated by the computer model we are using must be considered approximate, because we could not fully incorporate the provisions for flexibility in achieving emission reduction specified in both the Mitchell and Moynihan bills. Let me list the constraints of our analysis:[6]

1. Only sulfur dioxide emissions are considered. Though the bills specify a substitution of two tons of nitrogen oxides for one ton of sulfur dioxide, we do not yet have the capability to analyze the costs of this type of trade.

2. Only utility sulfur dioxide emissions reductions are considered. We have not yet examined the potential cost savings of emissions reductions obtained from non-utility industries.

Existing utilities are the only sources considered, and are assumed to be operating at their current percent of capacity utilization. Our analysis assumes that all reductions are accomplished immediately without accounting for new plants being built, or old plants being retired.

4. Only a finite list of control alternatives, employed singly or in combination, is considered. This includes a variety of fuel-use changes, coal washing, and wet and dry scrubbers. The current model analysis does not

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[6] The model used for this analysis is the AIRTEST model, run for us by Pechan and Associates, Inc. AIRTEST was modified from a larger model used in several earlier major assessments, including the New Source Performance Standards (NSPS) review, the Ohio River Basin Energy Study (ORBES), and the Acid Rain Mitigation Study (ARMS). The model estimates the cost of sulfur dioxide emissions reductions for each of about 2000 boilers in about 900 utility plants. The analysis assumes that the least expensive option will be chosen — either fuel switching, fuel blending, scrubbers, or some combination. The premium paid for lower sulfur fuels is estimated by state. Scrubber costs vary by boiler size, the sulfur content of the fuel and percent sulfur dioxide removal required. Representative scrubber costs and fuel price differentials for low-sulfur coal are included in the appendix.

consider some of the control strategies mentioned in both bills, such as early retirement of major sources or reductions due to conservation or selective use of lower-emitting plants; likewise, the analysis does not consider the effects of new technologies which may be available within a decade.

IV. Some Further Comments.

Again, our analysis has not allowed the substitution of emission reductions from industrial boilers for utility emission reductions to achieve the target. Some preliminary analyses performed by ICF, Inc. can at least suggest the relative costs of emissions reductions from industrial boilers and utility boilers.[7] Table 5 is a comparison of the ICF industrial boiler analysis and comparable AIRTEST utility analyses. Though the potential for reduction from industrial boilers is not as large as from utility boilers, the costs, on a per ton of sulfur dioxide basis, may be about equal, and in some cases be lower, than for utility boiler emissions reductions.

Though some analyses have been performed for EPA and DOE on the costs of nitrogen oxide emission reductions, we have not reviewed the analyses in enough depth to report on the results. I would like to comment on the provisions of both bills which allow for trading nitrogen oxide emissions for sulfur dioxide. At the current time, our knowledge of baseline nitrogen oxide emissions is quite poor, relative to sulfur dioxide. It is harder to estimate the amount of current emissions on a plant-by-plant basis. In addition, the current knowledge of the available options and costs of controls for nitrogen oxide emission reductions is much poorer than for sulfur dioxide reductions.

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[7] ICF, Inc. "ICF Study of Air Pollution Emission by the Manufacturing Sector," Memorandum from C. Hoff Stauffer to M. Wagner and M. Kelly, EPA.

In our final report on transported air pollutants, scheduled for completion next spring, we hope to provide estimates of the costs of both industrial sulfur dioxide emissions reductions and nitrogen oxide emissions reductions. While my testimony today has focused on the costs of utility emissions reductions specified by the two bills, another major element of our study, which I have not discussed at all in this testimony, is an examination of the potential benefits of controlling transported air pollutants. This concludes my written statement, Mr. Chairman. I will be happy to answer any questions.

Table 1

1980 Eastern U.S. SO_2 Emissions (10^3 Tons)

State	State Total	% Utilities
Alabama	739.8	76%
Arkansas	78.9	34%
Connecticut	149.1	22%
Delaware	90.8	58%
District of Columbia	44.4	10%
Florida	933.7	78%
Georgia	837.7	87%
Illinois	1532.8	74%
Indiana	2079.8	74%
Iowa	344.3	68%
Kentucky	1108.0	89%
Louisiana	260.5	10%
Maine	98.4	17%
Maryland	330.0	68%
Massachusetts	477.7	58%
Michigan	931.7	61%
Minnesota	294.0	61%
Mississippi	196.1	67%
Missouri	1348.6	85%
New Hampshire	109.0	74%
New Jersey	362.0	30%
New York	1078.9	45%
North Carolina	618.5	71%
Ohio	2802.6	77%
Pennsylvania	2165.6	67%
Rhode Island	32.1	16%
South Carolina	315.6	70%
Tennessee	1086.0	86%
Vermont	15.0	3%
Virginia	326.7	50%
West Virginia	1093.6	87%
Wisconsin	618.8	72%
TOTALS	22,500.7	71%

Source: Phase III (Final) Emissions Inventory by U.S./Canada Work Group 2, Report No. 2-B (Draft), September 4, 1981.

Table 2

SO_2 Emission Reductions Required by the Mitchell Bill (10^3 Tons)

State	State Total	Target Reductions Before SIP Compliance	Final Target Reductions After SIP Compliance
Alabama	739.8	303.5	194.1
Arkansas	78.9	0.6	0.0
Connecticut	149.1	0.0	0.0
Delaware	90.8	16.9	16.9
District of Columbia	44.4	0.0	0.0
Florida	933.7	340.6	322.7
Georgia	837.7	452.6	436.4
Illinois	1532.8	770.2	741.9
Indiana	2079.8	1191.3	1028.8
Iowa	344.3	128.9	108.6
Kentucky	1108.0	696.8	457.9
Louisiana	260.5	0.0	0.0
Maine	98.4	2.7	2.7
Maryland	330.0	109.8	109.6
Massachusetts	477.7	106.4	71.6
Michigan	931.7	238.2	190.1
Minnesota	294.0	67.0	66.8
Mississippi	196.1	73.3	73.3
Missouri	1348.6	911.1	911.1
New Hampshire	109.0	50.1	37.5
New Jersey	362.0	38.2	38.2
New York	1078.9	226.5	193.3
North Carolina	618.5	89.0	89.0
Ohio	2802.6	1617.5	1335.0
Pennsylvania	2165.6	876.7	750.9
Rhode Island	32.1	0.0	0.0
South Carolina	315.6	97.0	97.0
Tennessee	1086.0	679.0	423.6
Vermont	15.0	0.1	0.1
Virginia	326.7	26.0	0.0
West Virginia	1093.6	582.4	561.7
Wisconsin	618.8	308.1	306.7
TOTALS	22,500.7	10,000.0	8,565.2

Source: Office of Technology Assessment

Table 3

SO_2 Emission Reductions Required by the Moynihan Bill (10^3 Tons)

State	State Total	Emissions Reductions Specified by Bill
Alabama	739.8	107.0
Arkansas	78.9	0.0
Connecticut	149.1	0.0
Delaware	90.8	0.0
District of Columbia	44.4	0.0
Florida	933.7	256.7
Georgia	837.7	269.0
Illinois	1532.8	596.9
Indiana	2079.8	1011.7
Iowa	344.3	0.0
Kentucky	1108.0	547.1
Louisiana	260.5	0.0
Maine	98.4	0.0
Maryland	330.0	0.0
Massachusetts	477.7	0.0
Michigan	931.7	55.7
Minnesota	294.0	0.0
Mississippi	196.1	56.0
Missouri	1348.6	749.5
New Hampshire	109.0	44.5
New Jersey	362.0	0.0
New York	1078.9	44.2
North Carolina	618.5	0.0
Ohio	2802.6	1208.0
Pennsylvania	2165.6	648.3
Rhode Island	32.1	0.0
South Carolina	315.6	0.0
Tennessee	1086.0	508.6
Vermont	15.0	0.0
Virginia	326.7	0.0
West Virginia	1093.6	535.9
Wisconsin	618.8	49.3
TOTALS	22,500.7	6688.2

Source: Office of Technology Assessment

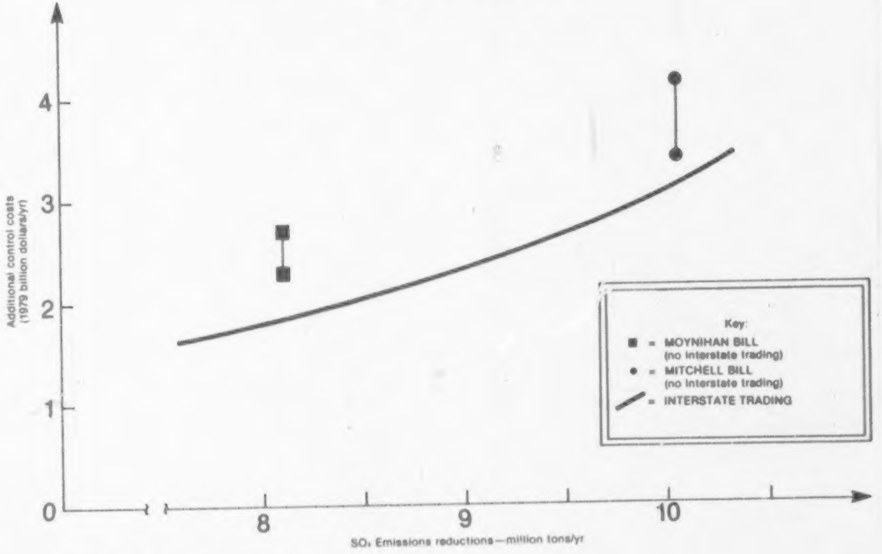
Table 4

Comparison Between Mitchell and Moynihan Bills Eastern U.S. Sulfur Dioxide Emissions, (10^3 Tons)

State	Current Sulfur Dioxide Emissions	Mitchell Bill Percent Below Current Emissions	Moynihan Bill Percent Below Current Emissions
Alabama	739.8	41.0	29.3
Arkansas	78.9	4.8	4.8
Connecticut	149.1	0.3	0.3
Delaware	90.8	18.7	0.0
District of Columbia	44.4	0.0	0.0
Florida	933.7	36.5	29.4
Georgia	837.7	54.0	34.0
Illinois	1532.8	50.2	40.8
Indiana	2079.8	57.3	56.5
Iowa	344.3	37.4	5.9
Kentucky	1108.0	62.9	70.9
Louisiana	260.5	0.0	0.0
Maine	98.4	2.8	0.0
Maryland	330.0	33.3	0.0
Massachusetts	477.7	22.2	7.3
Michigan	931.7	25.6	11.1
Minnesota	294.0	22.8	0.0
Mississippi	196.1	37.3	28.5
Missouri	1348.6	67.6	55.6
New Hampshire	109.0	46.1	52.3
New Jersey	362.0	10.6	0.0
New York	1078.9	21.0	7.1
North Carolina	618.5	14.4	0.0
Ohio	2802.6	57.8	53.2
Pennsylvania	2165.6	40.5	35.7
Rhode Island	32.1	0.0	0.0
South Carolina	315.6	30.7	0.0
Tennessee	1086.0	62.5	70.4
Vermont	15.0	0.7	0.0
Virginia	326.7	28.4	28.4
West Virginia	1093.6	53.2	50.9
Wisconsin	618.8	49.8	8.2
TOTALS	22,500.7	44.8	36.4

Source: Office of Technology Assessment

Figure 1.—Costs of Utility SO_2 Emission Reductions
(excludes costs to meet current regulations)



SOURCE: Airtest model, Pechan and Associates, Inc., 1981

Table 5

Comparison of Industrial Boiler and Utility Boiler Analyses

	4 Pound Capacity		2 Pound Capacity		1.5 Pound Capacity	
	Industry	Utility	Industry	Utility	Industry	Utility
Total Reduction (1000 tons)	468	1,308	1,066	4,929	1,288	6,416
Percent Reduction	10.8	8.5	24.8	32.1	30.0	41.8
Average Cost of Reduction ($/ton)	98	202	257	324	342	357

Source: AIRTEST, EHPA Analysis of ICF, Inc. (1981). "ICF Study of Air Pollution Emission by the Manufacturing Sector", Memo from C.H. Stauffer to M. Wagner and M. Kelly, EPA.

Table A-1

1980 Eastern U.S. SO_2 Emissions (10^3 Tons)

State	Utilities		Industrial Combustion		Other*		Non-Utility State Total		Overall State Total
Alabama	563.7	76%	93.1	13%	83.0	11%	176.1	24%	739.8
Arkansas	26.5	34%	26.5	34%	25.9	33%	52.4	66%	78.9
Connecticut	32.2	22%	54.3	36%	62.6	42%	116.9	78%	149.1
Delaware	52.5	58%	14.5	16%	23.8	26%	38.3	42%	90.8
District of Columbia	4.6	10%	4.5	10%	35.3	80%	39.8	90%	44.4
Florida	725.8	78%	86.5	9%	121.4	13%	207.9	22%	933.7
Georgia	726.3	87%	46.1	6%	65.3	8%	111.4	13%	837.7
Illinois	1127.8	74%	176.9	12%	228.1	15%	405.0	26%	1532.8
Indiana	1536.5	74%	358.0	17%	185.3	9%	543.3	26%	2079.8
Iowa	232.5	68%	71.5	21%	40.3	12%	111.8	32%	344.3
Kentucky	983.1	89%	69.1	6%	55.8	5%	124.9	11%	1108.0
Louisiana	25.0	10%	53.4	21%	182.1	70%	235.5	90%	260.5
Maine	16.3	17%	33.1	34%	49.0	50%	82.1	83%	98.4
Maryland	223.2	68%	45.3	14%	61.5	19%	106.8	32%	330.0
Massachusetts	275.5	58%	32.4	7%	169.8	36%	202.2	42%	477.7
Michigan	565.4	61%	157.3	17%	209.0	22%	366.3	39%	931.7
Minnesota	180.2	61%	42.2	14%	71.6	24%	113.8	39%	294.0
Mississippi	132.2	67%	20.5	10%	43.4	22%	63.9	33%	196.1
Missouri	1139.7	85%	84.4	6%	124.5	9%	208.9	15%	1348.6
New Hampshire	80.3	74%	6.7	6%	22.0	20%	28.7	26%	109.0
New Jersey	110.2	30%	46.0	13%	205.8	57%	251.8	70%	362.0
New York	488.3	45%	170.9	16%	419.7	39%	590.6	55%	1078.9
North Carolina	435.8	71%	94.1	15%	88.6	14%	182.7	30%	618.5
Ohio	2168.7	77%	377.6	13%	256.3	9%	633.9	23%	2802.6
Pennsylvania	1441.8	67%	284.8	13%	439.0	20%	723.8	33%	2165.6
Rhode Island	5.2	16%	5.1	16%	21.8	68%	26.9	84%	32.1
South Carolina	219.6	70%	68.6	22%	27.4	9%	96.0	30%	315.6
Tennessee	933.7	86%	88.9	8%	63.4	6%	152.3	14%	1086.0
Vermont	0.4	3%	3.1	21%	11.5	77%	14.6	97%	15.0
Virginia	163.2	50%	98.8	30%	64.7	20%	163.5	50%	326.7
West Virginia	947.1	87%	99.4	9%	47.1	4%	146.5	13%	1093.6
Wisconsin	448.1	72%	96.1	16%	74.6	12%	170.7	28%	618.8
TOTALS	16,011.4	71%	2909.6	13%	3579.6	16%	6489.3	29%	22,500.7

Source: Phase III (Final) Emissions Inventory by U.S./Canada Work Group 2, Report No. 2-4 (Draft), September 4, 1981.

* Other includes residential/commercial, transportation, petroleum refineries, iron and steel, non-ferrous smelting, paper and pulp, and solid waste incineration emissions.

Table A-2

SO_2 Emission Reductions Required by the Mitchell Bill (10^3 Tons)

State	State Utility Emissions	Emissions Greater Than 1.2 lbs/MMBtu	Allocation Formula (% Eastern Reductions)	Target Reductions Before SIP Compliance	Final Target Reductions After SIP Compliance
Alabama	563.7	281.6	3.0	303.5	194.1
Arkansas	26.5	0.6	0.0	0.6	0.0
Connecticut	32.2	0.0	0.0	0.0	0.0
Delaware	52.5	15.7	0.2	16.9	16.9
District of Columbia	4.6	0.0	0.0	0.0	0.0
Florida	725.8	316.0	3.4	340.6	322.7
Georgia	726.3	419.9	4.5	452.6	436.4
Illinois	1127.8	714.5	7.7	770.2	741.9
Indiana	1536.5	1105.2	11.9	1191.3	1028.8
Iowa	232.4	119.6	1.3	128.9	108.6
Kentucky	983.1	646.4	7.0	696.8	457.9
Louisiana	24.9	0.0	0.0	0.0	0.0
Maine	16.3	2.5	0.0	2.7	2.7
Maryland	223.2	101.9	1.1	109.8	109.6
Massachusetts	275.5	98.7	1.1	106.4	71.6
Michigan	565.4	221.0	2.4	238.2	190.1
Minnesota	180.2	62.2	0.7	67.0	66.8
Mississippi	132.2	68.0	0.7	73.3	73.3
Missouri	1139.7	845.2	9.1	911.1	911.1
New Hampshire	80.3	46.5	0.5	50.1	37.5
New Jersey	110.2	35.4	0.4	38.2	38.2
New York	488.5	210.1	2.3	226.5	193.3
North Carolina	435.8	82.6	0.9	89.0	89.0
Ohio	2168.7	1500.6	16.2	1617.5	1335.0
Pennsylvania	1441.8	813.3	8.8	876.7	750.9
Rhode Island	5.2	0.0	0.0	0.0	0.0
South Carolina	219.6	90.0	1.0	97.0	97.0
Tennessee	933.7	629.9	6.8	679.0	423.6
Vermont	0.4	0.1	0.0	0.1	0.1
Virginia	163.2	24.1	0.3	26.0	0.0
West Virginia	947.1	540.3	5.8	582.4	561.7
Wisconsin	448.3	285.8	3.1	308.1	306.7
TOTALS	16,011.3	9277.2	100.0	10,000.0	8,565.2

Source: Office of Technology Assessment

Alabama	125.9	107.0	454.3	1.9	227.2	107.0
Arkansas	0.0	0.0	22.7	0.4	-	0.0
Connecticut	0.0	0.0	31.8	0.5	-	0.0
Delaware	0.0	0.0	52.5	1.5	-	0.0
District of Columbia	0.0	0.0	0.0	0.0	-	0.0
Florida	302.0	256.7	707.9	1.7	353.9	256.7
Georgia	316.4	269.0	710.0	2.8	532.5	269.0
Illinois	702.2	596.9	1099.5	2.7	824.7	596.9
Indiana	1190.2	1011.7	1373.9	3.7	1030.5	1011.7
Iowa	0.0	0.0	212.1	2.0	-	0.0
Kentucky	643.7	547.1	744.1	2.7	558.1	547.1
Louisiana	0.0	0.0	24.9	0.1	-	0.0
Maine	0.0	0.0	16.3	1.4	-	0.0
Maryland	0.0	0.0	223.0	2.2	-	0.0
Massachusetts	0.0	0.0	240.7	1.5	-	0.0
Michigan	65.5	55.7	517.2	1.7	258.6	55.7
Minnesota	0.0	0.0	180.0	1.5	-	0.0
Mississippi	65.9	56.0	132.2	1.3	66.1	56.0
Missouri	881.7	749.5	1139.7	4.5	854.8	749.5
New Hampshire	52.4	44.5	67.7	2.4	50.7	44.5
New Jersey	0.0	0.0	110.2	0.9	-	0.0
New York	51.9	44.2	455.2	1.3	227.6	44.2
North Carolina	0.0	0.0	435.8	1.5	-	0.0
Ohio	1421.2	1208.0	1886.2	3.3	1414.7	1208.0
Pennsylvania	762.7	648.3	1316.0	2.3	987.0	648.3
Rhode Island	0.0	0.0	5.2	1.0	-	0.0
South Carolina	0.0	0.0	219.6	2.0	-	0.0
Tennessee	784.5	666.9	678.2	2.7	508.6	508.6
Vermont	0.0	0.0	0.0	0.0	-	0.0
Virginia	0.0	0.0	70.3	0.6	-	0.0
West Virginia	630.5	535.9	926.3	2.7	694.8	535.9
Wisconsin	58.0	49.3	446.8	3.1	335.1	49.3
TOTAL						6688.2

Source: Office of Technology Assessment

Table A-4

Comparison Between Mitchell and Moynihan Bills Eastern U.S. Sulfur Dioxide Emissions, (10^3 Tons)

State	Current Sulfur Dioxide Emissions	Mitchell Bill Emissions	Mitchell Bill Percent Below Current Emissions	Moynihan Bill Emissions	Moynihan Bill Percent Below Current Emissions
Alabama	739.8	463.3	41.0	523.4	29.3
Arkansas	78.9	75.1	4.8	75.1	4.8
Connecticut	149.1	148.7	0.3	148.7	0.3
Delaware	90.8	73.8	18.7	90.8	0.0
District of Columbia	44.4	44.4	0.0	44.4	0.0
Florida	933.7	593.0	36.5	659.0	29.4
Georgia	837.7	385.1	54.0	552.5	34.0
Illinois	1532.8	762.7	50.2	907.7	40.8
Indiana	2079.8	888.5	57.3	905.5	56.5
Iowa	344.3	215.3	37.4	323.9	5.9
Kentucky	1108.0	411.2	62.9	321.9	70.9
Louisiana	260.5	260.4	0.0	260.4	0.0
Maine	98.4	95.7	2.8	98.4	0.0
Maryland	330.0	220.2	33.3	329.8	0.0
Massachusetts	477.7	371.3	22.2	442.9	7.3
Michigan	931.7	693.4	25.6	827.9	11.1
Minnesota	294.0	227.0	22.8	293.8	0.0
Mississippi	196.1	122.9	37.3	140.1	28.5
Missouri	1348.6	437.5	67.6	599.1	55.6
New Hampshire	109.0	58.8	46.1	51.9	52.3
New Jersey	362.0	323.8	10.6	362.0	0.0
New York	1078.9	852.6	21.0	1001.7	7.1
North Carolina	618.5	529.4	14.4	618.5	0.0
Ohio	2802.6	1185.1	57.8	1312.1	53.2
Pennsylvania	2165.6	1288.9	40.5	1391.5	35.7
Rhode Island	32.1	32.1	0.0	32.1	0.0
South Carolina	315.6	218.6	30.7	315.6	0.0
Tennessee	1086.0	407.0	62.5	321.8	70.4
Vermont	15.0	14.9	0.7	15.0	0.0
Virginia	326.7	233.8	28.4	233.8	28.4
West Virginia	1093.6	511.2	53.2	536.9	50.9
Wisconsin	618.8	310.9	49.8	568.2	8.2
TOTALS	22,500.7	12,429.6	44.8	14,306.5	36.4

Source: Office of Technology Assessment

Table A-5

Comparison Between Mitchell and Moynihan Bills
Calculated as if all Reductions from Utility Sector
Eastern U.S. Sulfur Dioxide Emissions 10^3 Tons

State	Current Utility Emissions	SIP Compliance Emission	% Reduction Below Current Utility	Mitchell Bill Emissions	% Reduction Below Current Utility	Moynihan Bill Emissions	% Reduction Below Current Utility
Alabama	563.7	454.3	9.4	260.2	53.8	347.3	38.4
Arkansas	26.5	22.7	14.6	22.7	14.6	22.7	14.6
Connecticut	32.2	31.8	1.2	31.8	1.2	31.8	1.2
Delaware	52.5	52.5	0.0	35.5	32.3	52.5	0.0
District of Columbia	4.6	4.6	0.0	4.6	0.0	4.6	0.0
Florida	725.8	707.9	2.5	385.1	46.9	451.1	37.8
Georgia	726.3	710.0	2.2	273.7	62.3	441.1	39.3
Illinois	1127.8	1099.5	2.5	357.7	68.3	502.7	55.4
Indiana	1536.5	1373.9	10.6	345.2	77.5	362.2	76.4
Iowa	232.4	212.1	8.7	103.5	55.5	212.1	8.7
Kentucky	983.1	744.1	24.3	286.3	70.9	197.0	80.0
Louisiana	24.9	24.9	0.0	24.9	0.0	24.9	0.0
Maine	16.3	16.3	0.0	13.6	16.6	16.3	0.0
Maryland	223.2	223.0	0.1	113.4	49.2	223.0	0.1
Massachusetts	275.5	240.7	12.6	169.1	38.6	240.7	12.6
Michigan	565.4	517.2	8.5	327.1	42.1	461.6	18.4
Minnesota	180.2	180.0	0.1	113.2	37.2	180.0	0.1
Mississippi	132.2	132.2	0.0	59.0	55.4	76.2	42.4
Missouri	1139.7	1139.7	0.0	228.6	79.9	390.2	65.8
New Hampshire	80.3	67.7	15.7	30.1	62.5	23.2	71.1
New Jersey	110.2	110.2	0.0	72.0	34.6	110.2	0.0
New York	488.5	455.2	6.8	262.0	46.4	411.1	15.8
North Carolina	435.8	435.8	0.0	346.7	20.4	435.8	0.0
Ohio	2168.7	1886.2	13.0	551.2	74.6	678.2	68.7
Pennsylvania	1441.8	1316.0	8.7	565.1	60.8	667.7	53.7
Rhode Island	5.2	5.2	0.0	5.2	0.0	5.2	0.0
South Carolina	219.6	219.6	0.0	122.6	44.2	219.6	0.0
Tennessee	933.7	678.2	27.4	254.7	72.7	169.5	81.8
Vermont	0.4	0.4	0.0	0.3	25.0	0.4	0.0
Virginia	163.2	70.3	56.9	70.3	56.9	70.3	56.9
West Virginia	947.1	926.3	2.2	364.7	61.5	390.4	58.8
Wisconsin	448.3	446.8	0.3	140.2	68.7	397.5	11.3
TOTALS	16,011.3	14,505.4	9.4	5,940.1	62.9	7,817.5	51.2

Source: Office of Technology Assessment

Table A-6

RETROFITTED LIMESTONE FGD SYSTEM
TOTAL INVESTMENT COST
6 LB. SO_2/MMBtu - No Spares
(1979 $)

MW	% REMOVAL	INVESTMENT $X 10^6	$/KW
500	90	87.47	175
	70	69.91	140
	50	48.40	97
200	90	42.33	212
	70	32.46	162
	50	28.86	129
100	90	26.75	268
	70	23.13	231
	50	17.80	178

Source: Adapted from MITRE Corporation (1981), "Acid Rain Mitigation (ARM) Study Final Utility and Industrial Boiler FGD Costs and Derived Cost Algorithms".

Table A-7

Sulfur Differentials Used in AIRTEST and Actual 1980 Values

Differential in 1979 Cents Per Pound SO_2

State	AIRTEST	1980 Form 423*
Ohio	22	7
Texas**	4	39
Pennsylvania	27	***
Illinois	11	14
Indiana	11	8
West Virginia	25	8
Kentucky	10	8
Missouri	17	5
Michigan	11	8
North Carolina	21	5

* Actual values converted to 1979 dollars.

** State not part of ARMS region.

*** No relationship could be derived.

Source: Statistical Analyses of AIRTEST inputs and 1980 Form 423 shipment data.

STATEMENT OF
KATHLEEN M. BENNETT
ASSISTANT ADMINISTRATOR FOR AIR, NOISE, AND RADIATION
U.S. ENVIRONMENTAL PROTECTION AGENCY
BEFORE THE
COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS
UNITED STATES SENATE

OCTOBER 29, 1981

Good morning, Mr. Chairman and members of Subcommittee. I am Kathleen M. Bennett, Assistant Administrator for Air, Noise, and Radiation of the U.S. Environmental Protection Agency. I am pleased to appear before you today to discuss the Agency's views on transboundary pollutant transport and acid deposition, in particular. Both have become issues of increasing global interest in recent years, and matters of concern to the Administration and to Congress.

Transboundary Pollutant Transport

It is widely recognized that pollutants can be carried in air masses across jurisdictional boundaries to cause transboundary and interstate air pollution.

Transport of pollutants can occur over three distances: (1) local--up to a maximum of 50 kilometers from a source; (2) medium range--covering areas of about 50 kilometers to 300 kilometers in extent; and (3) long range--covering regions of about 300 kilometers to 2000 kilometers in extent. Measured pollutant concentrations may, in some cases, be the cumulative impact of local, medium, and long-range transported emissions.

The most obvious documented examples of transboundary transport occur on a local scale, where individual sources located just across a state line cause high ambient pollutant concentrations in a downwind jurisdiction. These relatively simple source-receptor relationships often can be analyzed through use of conventional monitoring studies and sophisticated computer modeling techniques.

Several areas in the United States which contain a large number of emission sources are subject to medium-range air quality problems. When several major sources are located along the direction of prevailing wind flow, the background pollutant concentrations in downwind areas can be strongly influenced by the upwind sources.

There exists documentation that emissions can travel long distances to cause transboundary pollution. Such emissions may contribute to transboundary air pollution in two ways: by increasing air pollution concentrations and by depositing pollutants out of the atmosphere either dry as gases and particles or in all forms of precipitation. In the first case, adverse effects can derive from air pollution concentrations elevated above the national ambient air quality standards and from decreased visibility. In the second instance, damage could possibly result from dry and wet deposition of acidic compounds, heavy metals, and toxic organic substances.

I would like to concentrate now on acid deposition, which is a matter of much concern in our nation and in other nations as well.

Background

"Acid deposition" is a general term for the deposition of acidic materials, whether wet or dry, from the air onto the surface of the earth or upon structures or objects.

Neither acid deposition itself nor the terminology by which we describe it is of recent origin. Although references date back to 1661, most relevant research through the 1950's was conceived originally for other purposes. Historical lake surveys were done to assess fishery or water quality resources. Large scale precipitation chemistry networks were established by agricultural scientists to study precipitation as a source of plant nutrients, and atmospheric scientists even studied rain as method of removing air pollutants.

A synthesis of information from such independent disciplines by Swedish soil scientist Svante Oden in 1967 sparked scientific and public interest. Later, re-analyses of earlier precipitation chemistry data and studies of fish populations in the Adirondacks and Sudbury, Ontario, lakes stimulated North American interest. This led to the development of government and industry sponsored research programs in both the United States and Canada. Thus, the scientific study of acid deposition as a separate field is scarcely more than a decade old, and our understanding has improved considerably in the last five years.

Acid Deposition--Knowledge and Uncertainties

Acid deposition exists, and varying effects do occur, but there is considerable debate over the circumstances of its formation and the feasibility of potential controls. Scientists may see the same data on acid deposition and circumstantially associated pollutant emissions and reach quite different conclusions.

Currently, we do know something about the emissions of oxides of sulfur and nitrogen which can be the precursors of acid deposition. The majority of man-made emissions of sulfur oxides in the United States comes from utilities; the remainder comes from other combustion sources, non-ferrous smelters, and transportation sources. U.S. nitrogen oxide emissions come mainly from transportation and from utilities and industrial boilers.

We know that emissions tend to be highly interactive, and that multiple emissions must be considered simultaneously.

Both sulfur and nitrogen oxides can be transformed into nitrogen and sulfuric acids by reacting with the moisture as well as other substances in the atmosphere. These transformations can take place in cloud or rain droplets or after deposition. Depending on a number of variables, emissions may be deposited relatively near their sources or transported over long distances.

For all that is known about acid deposition, a number of major uncertainties in our current thinking remain to be resolved.

One uncertainty has been the pH level at which precipitation should be considered "acid." The conventional definition is based on pure water saturated with atmospheric carbon dioxide. It has a pH of 5.6, which is, therefore, the theoretical level of "normal" rainfall. Naturally occurring precipitation may be considerably more or less acidic.

In addition, although oxides of sulfur and nitrogen are precursors of acid deposition, the transformation processes are still not understood. While there are significant differences in the composition and acidity of rain between seasons, geographical regions, and even during and between storms, no clear evidence is yet available which can explain or predict accurately how precursors are transformed or why the observed variations occur.

Yet another uncertainty exists with regard to the transport and distribution of precursor emissions. Remote regions of the globe have rains with a low pH, as do Hawaii and Alaska, and there is controversy over the role that localized emission sources may play. To resolve such controversies, both better data and more accurate modeling techniques are necessary.

Additional uncertainties for which we need better data include the relative impact of local sources as compared to more distant sources the role of other photochemical pollutants and how they affect acidity levels; and the relative importance of the various effects from acid deposition (i.e., aquatics, forests, materials, etc.)

Need For Responsible Action

Any Administration action must be based on a reasonable degree of certainty that it will, in fact, accomplish its intended purpose. The American people have the right to expect that their government will not impose an additional multi-billion dollar program without first determining with some assurance that the intended environmental benefits will be achieved.

In this case, quick and simple solutions are unlikely. Given the length of time it has taken to recognize the magnitude and complexity of the problem and the many fundamental questions that remain to be answered, Congress wisely authorized a comprehensive research program.

Currently, in an effort to reduce uncertainties so that meaningful and effective program options can be considered, EPA is working on a number of projects.

EPA alone has committed more than $9 million in FY 1982 just to its research efforts on acid deposition; other Federal efforts will bring the total to more than $18 million.

The three major areas of uncertainty toward which EPA's portion of the research program is directed are:

(1) transport, transformation, and deposition processes;

(2) effects of acid deposition; and

(3) assessments and policy studies.

I have attached to my statement an inventory of the Agency's major research efforts in the acid deposition area. The funding levels listed with each project are approximate.

Other Federal Acid Deposition Research Activities

In 1980, Congress passed the Acid Precipitation Act. It established an interagency Acid Precipitation Task Force which is to prepare a ten-year comprehensive research plan to identify the causes and effects of Acid Deposition. Congress directed that an annual report be submitted "which shall detail the progress of the research program under this subtitle and which shall contain such recommendations as are developed."

The comprehensive research plan, entitled the National Acid Precipitation Assessment Plan, is currently being updated to incorporate public comments. EPA has been designated as the "lead agency" for three of the research areas, including aquatic effects, control technology, and data assessments and analysis.

Furthermore, the results of research from all sources, public and private, are compiled and evaluated in assessments that provide research support for regulatory decisionmaking.

Anticipated Research Results

Over the next three to five years, we anticipate that many ambiguities and uncertainties will be reduced. Specifically, we expect to have the following information:

- o Additional studies of historical lake, stream, and reservoir data.
- o The results of five models for predicting sulfate deposition on an annual basis.
- o Status reports on acid deposition effects on agricultural crops.

- A new report on the role of clouds and storm fronts in formulating and scavenging acids in the atmosphere.
- The results of pilot tests and a completed demonstration of new combustion processes for controlling oxides of nitrogen and sulfur dioxide at significantly reduced costs.
- A summary report on the impacts of acid deposition on materials.
- Additional results from Sweden on forest productivity.
- A progress report by the National Oceanic and Atmospheric Administration on acid rain in remote locations.
- An aquatic model for predicting the rate of acidification occurring in lakes.
- A series of second-generation models for predicting the transport and deposition of sulfur and nitrogen over long distances.
- Field studies validating laboratory experiments of the effects of acid deposition on selected major crops.

Global Transboundary Air Pollution Activities

Because transboundary air pollution is a global concern, EPA has been consulting with other interested countries, particularly Canada, and will continue to do so.

With the August 5, 1980, Memorandum of Intent on Transboundary Air Pollution, Canada and the United States agreed to begin cooperative steps to deal with transboundary air pollution and to develop a bilateral agreement. Formal negotiations began in June and are scheduled to resume next week.

Within this structure, Work Groups are preparing the technical summaries of currently available information. The Work Groups are comprised of representatives from EPA; the Departments of State, Agriculture, Interior, and Energy; the Council on Environmental Quality; the National Oceanic and Atmospheric Administration; and other agencies as well as representatives from corresponding Canadian departments. Interim Work Group reports currently under review and revision are due to be completed early next year.

Senate Amendments Addressing Long Range Transport

The amendments proposed by Senators Mitchell, Moynihan, and Dodd each provide mechanisms for dealing with acid deposition or, more broadly, the interstate transport of air pollutants.

Although the Mitchell and Moynihan bills are based on different equations, each basically calls for substantial reductions in SO_2 emissions over the next decade. In general, the impact of these reductions would fall primarily on those few states whose emissions sources rely most heavily on locally available high sulfur coals. Thus, some states will experience large (perhaps over 10%) increases in their utility bills while many other states will be virtually unaffected. This uneven impact could increase the tension already evident between states and make it more difficult to secure state cooperation in developing a cost-effective control strategy for acid deposition.

Although the regional impact of the proposed bills is obvious, EPA has not had an opportunity to analyze the consequences of these bills in detail. Therefore, I am not prepared to address the specific effects of the types of measures mandated in these bills. I would like to reiterate that the scientific uncertainty surrounding the causes and effects of acid deposition at this time demands that we proceed cautiously and avoid premature action, unless we have some confidence that the intended environmental benefits would be produced.

Since the passage of the Clean Air Act of 1970, it is estimated that our nation has spent approximately $150 billion on air pollution control. Those expenditures have been driven by our attempts to meet the health and welfare requirements of the Act. We estimate that the approach proposed in these bills could increase expenditures by roughly $2 to $4 billion per year. Further, the implementation scheme for both bills is unclear and could be exceedingly difficult to administer. These bills involve a radical new concept in pollution control based on a total loadings approach. Such an approach would represent a sweeping departure from our current national program which is based on protection of health and welfare through control of local ambient air quality levels. Before proceeding with such a dramatic and expensive overhaul of the underpinnings of our air clean-up efforts, we must better understand the need for and impact of a "loadings reduction" approach.

The amendments to sections 110(a)(2)(E) and 126 proposed by Senator Dodd are designed to improve the decision-making process on interstate petitions under section 126. While we support the goal and general approach of the bill, we are concerned about some of its specific provisions.

The most troubling aspect of the bill is the new penalty provision which requires the court to assess a penalty of $100,000 against the United States, if the Administrator fails to act on a petition within 120 days. I am deeply disturbed by the concept that the general taxpaying public would be punished for the Agency's failure to act within the short statutory period. This provision could serve as an incentive for a state to complicate the process--at the expense of taxpayers in other states. This provision could divert the attention and resources of the Agency from other statutorily mandated responsibilities. Delays already result from many factors, including the demands of meeting other statutory obligations, the complexity of interstate pollution questions, and the vagueness of the current statutory guidelines.

Currently, the Agency is seeking to reduce the complexities and uncertainties which have inhibited the implementation of Section 126. To improve the Agency's ability to evaluate petitions, the Agency announced at a Section 126 hearing in June 1981 that three showings should be made as part of any section 126 petition. These are a demonstration of the scope of the area subject to the petition, a demonstration that achievement of the national standards or measures necessary to prevent significant deterioration or protect visibility is prevented by named out-of-state sources, and an in-indication that sources within the petitioning state, which affect the area subject to the petition, have adequate pollution controls. The Agency is developing further guidance aimed at improving and accelerating its review of Section 126 petitions.

The Dodd bill adds to section 110(a)(2)(E) a new prohibition on pollutants from one state that "contribute to pollution which may reasonably be anticipated to endanger public health or welfare in any other state." This new basis for filing an interstate petition is similar to language now in section 115, concerning international air pollution, and suffers from the same difficulty as that language: it provides for control of pollutants for which no national ambient air quality standard has been set. In essence, it grants the Administrator broad discretion to require potentially costly emission reductions for pollution control, without provision for the type of scientific review and procedural protection provided in the national standard-setting process under sections 108 and 109.

We readily support the Dodd bill's concept of including a list of criteria which the Administrator must consider in acting on section 126 petitions. The criteria listed in the bill, however--such as total loadings of any pollutant from all sources in the area--are very difficult to quantify. This requirement places a heavy burden on the Administrator, the petitioning state, or both parties, depending who is required to provide the information. The bill does not indicate which party must provide the information.

Another problem is the bill's prohibition against sole reliance on only modeling or monitoring previously approved by the Administrator.

This means the Agency will have to devote considerable time and resources to evaluating new studies and modeling techniques.

A thorough assessment of such methods, which is necessary if they are to provide the basis for any action, cannot be accomplished within the 120-day period provided by the bill. Aside from the time constraints, we believe it would be unwise to evaluate new modeling or monitoring approaches in the context of individual Section 126 petitions. The factual background of an individual petition could distort the Agency's review of a particular method, especially if the Agency is faced with severe penalties for failure to act swiftly.

Summary

Acid deposition is a concern of many Americans, one shared by the Congress, and by the Administration. The depth of our concern about acid deposition should be reflected in public policies that are based on sound science.

As we have indicated, there are major uncertainties in many critical areas, particularly about the transportation and transformation of possible precursor emissions into acid deposition, the effects, and the policy implications of acid deposition. In passing the Acid Precipitation Act of 1980, Congress itself established a comprehensive intergovernmental and interdepartmental research plan so that the complexity of acid precipitation could be more fully addressed.

Without such a firm foundation on which to base our decisions on whether controls are necessary, in what areas and to what degree, any regulatory action at this time would involve guessing.

In view of the many fundamental scientific uncertainties; the possible substantial cost burden of additional controls; the extensive Congressional involvement, including the ten-year directive to investigate the problem; and the fact that current research is expected to provide us with better data and guidance, we look forward to fulfilling the perceptive, far-reaching and multi-disciplined approach of Congress, as embodied 16 months ago in Title VII of the Energy Security Act.

This concludes my prepared statement. I would be happy to respond to any questions you may have.

ATTACHMENT

Major EPA Research On Acid Deposition

To reduce uncertainty in the area of transport, transformation and deposition processes, we are studying the following:

- $800,000 for research on consolidating and reconciling current oxides of sulfur and nitrogen emissions information. This will create a data base that can be used to show an accurate pattern of the magnitude and geographic distribution of man-made sources of these pollutants. We will be able then to improve our prediction capabilities, particularly with regard to major emissions sources.
- $800,000 for systematic data collection and monitoring studies of deposition and for associated research to increase the data on trends in deposition, and to improve monitoring techniques for both wet and dry acid deposition.
- $3,100,000 for atmospheric process research to obtain a better understanding of the actual mechanics of atmospheric transport, transformation, and deposition.

In order to gain a fuller understanding of the effects which may result from acid deposition, our efforts include:

- $100,000 for health effects impact studies on the effect of acid deposition on drinking water supplies, surface water, and groundwaters.
- $250,000 on materials research to determine the portion of material corrosion attributable to acid deposition

rather than to ambient air pollutants or other sources. This will also investigate the extent and aggregate cost of such damages.

- $1,400,000 for aquatic research to estimate the total number of lakes affected by acid deposition, as well as the sensitivity of streams and lakes to acidification, and the rate at which acidification actually occurs. In addition, these water quality measurements must be integrated with improved data on the impact of acid deposition on fish and the food chain, in order to develop information for possible short-term and long-term preventive and restorative measures.
- $1,300,000 for terrestrial studies on acid impacts on forest soils, on soil nutrients, on leaching processes, and on soil chemistry changes. Both laboratory and field studies of acid deposition impacts on agriculture and major U.S. crops are also scheduled.

We are taking a broad look at possible policies and strategies, and their implications.

- $1,300,000 for assessments and policy studies which will identify possible research avenues leading to potential mitigation strategies. They will then analyze those options considering the weight of existing scientific knowledge, costs and benefits, geography, degree of effectiveness, and other factors.

STATEMENT OF ROBERT F. FLACKE, COMMISSIONER, DEPARTMENT OF ENVIRONMENTAL CONSERVATION, STATE OF NEW YORK

ACID PRECIPITATION AND LONG RANGE TRANSPORT OF AIR POLLUTANTS

Acid precipitation, like ozone and photochemical oxidant, is a complex secondary pollution problem which is often generated hundreds of miles from the impact area. The receptor areas usually have no legal control over the transmitter areas; thus, federal legislation is needed to provide such control. A better understanding of the solution to the problem can be achieved if the nature and extent of the problem can be defined. The classic "source, vector, receptor" model can be used to study pollutant formation, mode of transmission and effects. In any such model, one starts with the effects and works backward.

EFFECTS

Acid precipitation is slowly taking its toll in New York and, indeed, throughout the Northeastern United States and Canada. Wilderness mountain lakes and ponds, productive farm land, agricultural crops, soils and buildings - all of these, and perhaps more, may be falling prey to this subtle form of air pollution.

Acid precipitation does not produce immediate dramatic effects. There are, thus far, no dead bodies or vast acreages of wastelands to attest to the effects of this insidious form of air pollution. There are, however, hundreds of lakes in New York State which no longer support diverse aquatic ecosystems, including sport fish populations. These lakes and streams were once an important natural heritage, a source of recreation and spiritual uplifting for many thousands of citizens - not only of New York but of much of the East. The loss of these resources is serious, but even more disturbing is the fact that many other lakes are beginning to exhibit changes, with populations of some fish gone and others on their way to disappearing. We fear that this present, and spreading, deterioration of our natural resources is only the first indication of subtle widespread damage from nearly invisible air pollutants.

Acid rain is a nationwide - even a worldwide - problem, of growing impact. The New York State Department of Environmental Conservation (DEC) recognized the possible significance of acid precipitation to fishery resources in the Adirondack region early in the 1970s. Since 1975, the Department has identified 468 lakes and ponds, comprising over 73,000 acres in the Adirondack region of New York, which chronically exhibit pH conditions below 6. This represents more than 27% of all the ponded water in the Adirondacks. More than 200 lakes (comprising over 10,000 acres) exhibit summer pH values of less than 5, and are generally unable to maintain any type of either native or stocked sport fish populations. The details of these studies are summarized in a 1980 DEC report by Martin Pfeiffer and Patrick Festa, entitled "Acidity Status of Lakes in the Adirondack Region of New York in Relation to Fish Resources" (copy attached).

A number of the points I wish to emphasize are detailed in the current issue of the Conservationist, published by DEC.

Most fish species, many aquatic plants, and invertebrates cannot tolerate acid levels below pH 5. At that level, metabolic and reproductive activities in fish and invertebrates are upset, often eliminating whole populations and disrupting existing biological communities. This has happened, and is still happening, in our Adirondack lakes.

Surveys over the last two years show that streams are also being affected. Fish and their food organisms no longer survive in several streams which once supported active fisheries. Much more needs to be done in determining effects in flowing water, but such research is expensive and takes time.

In addition to direct acidity effects on aquatic life, acid rain creates toxic conditions in waters by leaching toxic metals from the soils and sediment of streams and rivers. Aluminum, a metal particularly toxic to fish, has been found in acid waters of the Adirondacks in excess of levels proven to be toxic in laboratory studies. Mercury is another element which accumulates in fish and has created a public health concern in several waters of the state. Lakes which consistently produce fish with mercury levels above the tolerance level established by the Food and Drug Administation (1 milligram per kilogram) are primarily found in the Adirondack region, where no significant industrial sources are known. Mercury levels in fish flesh are declining throughout the state except in the Adirondack region. Acid precipitation appears to be linked to this uptake of mercury by the fish. The New York State Department of Health has advised residents to eat fresh water fish no more than once per week, and advises pregnant women and nursing mothers not to eat fish with elevated levels of mercury at all.

But, fish and anglers are not the only ones to suffer. In addition to documented effects on fishery resources, acid precipitation has been implicated in adverse effects on terrestrial ecosystems, building materials, visibility, and perhaps man himself. Vegetation, including crops, may be affected by acid prepcipitation. Researchers have shown that the deterioration of masonry occurs when acidic substances dissolve such materials as limestone and marble. Acid deposition also destroys sculptured details, as seen by the deterioration of hieroglyphics on Cleopatra's Needle in New York Central Park and the deterioration of the Statue of Liberty in New York Harbor.

Another adverse effect of acid precipitation is reduced visibility in the Northeast. Fine particles - precursors to acid rain - scatter and absorb light. The most dramatic reduction in visibility occurs in the summer, when reductions of 25 to 60 percent have been documented in the Northeast.

Of all areas of concern, human health is probably the least well understood but, at the same time, of utmost concern to us all. Identifying aquatic and terrestrial losses due to acid rain is important, to be sure. It can also serve as an omen of a potential danger for humans. Dr. Wolfgang Fuhs of the New York State Department of Health presented a summary on some of these effects at the Action Seminar on Acid Precipitation in Toronto in November of 1979 (copy of this paper is attached). He notes that the effects of acid precipitation on public health are the result of two different phenomena. "One is the presence in the atmosphere of acidic constituents which alone, or in combination with other pollutants, directly affect the human respiratory system. The other is the fact that acid rain has a corrosive property which causes toxic heavy metals to be rendered soluble in water and, thus, then leads to the appearance of these metals in drinking water..." Dr. Fuhs goes on to note that lead and copper levels in well water from the Adirondack region have been found to exceed U.S. drinking water standards.

DAMAGE ASSESSMENT

New York has not made an independent assessment of the economic losses created by acid precipitation. The state did, however, participate in preparation of the "Northeast Damage Report," prepared in April of 1981 for the Northeast States for Coordinated Air Use Management and the New England Interstate Water Pollution Control Commission. This report pegs the annual cost at 250 to 500 million dollars for damage to both aquatic and terrestrial economic assistance in New York and New England. This includes losses to recreational fishing and related tourism; drinking water supply treatment; lumber, paper and related industries; crops and other vegetation losses; and man-made materials, such as buildings and monuments. The report notes that these losses are conservative and could be as high as 2.5 billion dollars per year if other secondary and human costs are considered.

Documenting this destruction is important, and quantifying it in economic terms is one way to document the destruction. However, many values that the wilderness area of the Adirondacks offers cannot be easily converted into dollars and cents. The Adirondacks represent the only substantial area of wilderness in the northern part of the United Staes. The livelihood of the residents in that area is based primarily on tourism, and this way of life is jeopardized by acid precipitation. Those citizens who look to the Adirondacks for recreational and spiritual values are also suffering. The value of these losses is not easily calculated.

TRANSPORT

Upon emission to the atmosphere, the acid precipitation precursor pollutants are transported by the prevailing winds to receptor areas. During this transport process, these precursors undergo the various chemical reactions which ultimately produce the strong acids which increase the acidity of precipitation.

Essentially, all the primary emissions of sulfur are in the form of sulfur dioxide (SO_2). Atmospheric chemistry oxidizes SO_2 to sulfuric acid (H_2SO_4) and various sulfates. This oxidation occurs either through homogeneous gas phase reactions or through heterogeneous reactions.

Recent work has established the reactions of importance for the homogeneous reactions. Primary among these are the $OH + SO_2 + M$ oxidation reaction, (OH is the hydroxyl radical and M is any electron receptor). In polluted atmospheres (hydrocarbon), the peroxy radical (HO_2) becomes increasingly important in the oxidation of SO_2. This radical chemistry suggests daylight oxidation.

The heterogeneous reaction pathways are much less clear. The potentially important mechanisms, all of which require the absorption of SO_2 into an aqueous droplet, are: 1) dissolved SO_2 can be oxidized by strong oxidants (O_3 or H_2O_2); 2) by dissolved oxygen in the presence of a catalyst; or 3) by dissolved oxygen with no catalyst.

The chemistry of nitrogen is complex and not well understood. The most important form of nitrogen involved in formation of acid precipitation is nitric oxide (NO). It is oxidized to nitrous oxide (NO_2) which is, in turn, rapidly converted to nitric acid (HNO_3). These reactions are likely to involve hydroxyl radicals and may at times involve heterogeneous pathways.

The source-receptor transport relationship for New York and the Midwest is graphically illustrated by Coffey, et al(1) in a set of air parcel trajectories traced backward from three New York receptor sites over a period between June 15 and August 14, 1977. Figures 1 and 2 are examples for low sulfate concentration days and high concentration days at Whiteface Mountain.

This report showed that the days of relatively low sulfate concentrations at the Holland, Schoharie County, and Whiteface sites occurred in air which originated from areas northwest of New York, while days of relatively high sulfate concentrations at the same site were associated with air which had passed through the area southwest of New York. Also, the authors note that the highest ambient sulfate concentrations occur in New York during brisk southwesterly winds which have followed a stagnation period in the Midwest 12 to 36 hours earlier. It is evident that elevated sulfate concentrations in New York are associated with air transported from the area southwest of New York, an area of high SO_2 emissions. Similar conclusions were reached from the seven-year, seven-million-dollar EPRI Sulfate

Regional Experiment (SURE).(2) During this study elevated sulfate levels were also found to be associated with air which stagnated in the Midwest and was rapidly "ducted" to the Northeast.

Deposition of atmospheric acids can occur during distinct precipitation events--primarily rain, dew or snow--or through dry deposition, in which fine particles are deposited in an aerosol form or along with larger particulate material upon which they have been adsorbed.

Dry deposition has been difficult to measure with accuracy, but best estimates are that 50 percent of the total acid deposition is the resultant of this process. The lack of knowledge concerning dry deposition velocities gives a very low confidence to these estimates.

SOURCES AND CAUSES OF ACID PRECIPITATION

Understanding the total acid precipitation problem requires intensive study to probe the underlying causes. There is generally strong scientific consensus that atmospheric sulfates and nitrates are prime contributors to acid precipitation. These compounds may be transported many miles in the upper atmosphere before they are washed out as acid rain. Although we may not fully understand the sources of mechanisms by which acid precipitation is formed, considerable information is available. The U.S. Environmental Protection Agency has estimated that man-made sources of sulfur oxide emissions to the atmosphere may equal natural sources on a global basis; thus, man has essentially doubled the amount of sulfur dioxide in the atmosphere from what it would be naturally. On a regional basis, a University of Washington Study found that less than 2.5 percent of the sulfur emitted in the Northeastern United States is of natural origin. In the United States, EPA reported that, during 1977, more than two-thirds of those sulfur emissions originated in the vicinity of the Ohio River Valley as a result of fossil fuel combustion.

The distribution of these emissions is of great importance. Figure 3 is a map showing the distribution of sulfur dioxide emissions by state. Many states to the south and west of New York have particularly high sulfur dioxide emissions; for example, Ohio's emissions of 8,165 metric tons/day are over eight times those of New York. Similarly, Pennsylvania's emissions are eight times those of New York, and Illinois and Indiana have emissions five times those of New York. As discussed previously in the Transport section, elevated sulfate levels in New York are associated with air which first stagnates in this area of high sulfur dioxide emissions.

Nitrogen oxide emissions also contribute to acid precipitation. There is less agreement on the human contribution to nitrogen oxide emissions, but available data suggest that at least half of the emissions result from stationary fuel combustion, with half of that coming from the generation of electricity. Motor vehicles also account for substantial emissions of nitrogen oxides.

MITIGATION AND CONTROL

Methods are available to mitigate some of the effects of acid precipitation and to control sulfur and nitrogen oxide emissions at the source. New York State has begun to mitigate the effects of acid precipitation on Adirondack lakes by applying agricultural lime to a few of them. This is a costly procedure, and treatment is required every three to five years to maintain adequate pH levels for the survival of fish. Liming the thousands of Canadian lakes would require such an extensive capital and annual expenditure as to be impractical.

It is not clear, however, that liming can restore a lake's ability to support naturally reproducing biological communities, including fish. It is unlikely that the primary attribute for which people prize the Adirondacks - its wilderness value - will be preserved if intensive liming were proposed as a method of mitigating the effects of acid precipitation in the Adirondacks. Liming would obviously not correct most of the other effects of acid precipitation. Furthermore, liming is like applying a bandaid to a sore, but continually aggravating the wound so that it never heals completely.

Atmospheric emissions of sulfur dioxide can be reduced by requiring low sulfur fuel, by scrubbing emissions from power plants, by washing or cleaning sulfur from coal, or combinations of these techniques. We do not see any of these strategies as being a complete solution, but we do believe that coal washing should be implemented now and would be the most cost effective option for existing utilities. Scrubbing may be a reasonable option for some existing plants, but probably not for all.

Atmospheric emissions of nitrogen oxides from stationary sources can best be reduced through modification to design of the burning equipment through staged combustion or other techniques which reduce the formation of nitrogen oxides. Reduction of emissions from mobile sources is best accomplished through the gradual replacement of older high NO_x vehicles with newer, low NO_x vehicles. Therefore, we were dismayed to learn that a strong move is underway to amend the Clean Air Act to allow increased nitrogen oxide emissions from motor vehicles. It is important not to lose the regulatory headway we have made against this component of acid rain.

New York State has pioneered in efforts to seek a federal solution to this nationwide problem. We have petitioned the U.S. Environmental Protection Agency in an effort to convince that agency that the problem is interstate and cannot be solved by any one state alone. New York has formed a coalition with several other Northeast and Mid-Atlantic States to push for federal action.

New York's Senior Senator, Daniel Patrick Moynihan, has won Congressional authorization for a national research program to explore and document the problem over the next decade. We hope that this program can be accomplished sooner - within the next five years. While this reseach program is underway, we believe that the nation needs: a national coal washing program to require the cleaning of coal with a sulfur content greater than three percent; retrofitting existing power plants for staged combustion to cut down on nitrogen oxide emissions; and an early determination of the feasibility of establishing national emission standards for sulfates and nitrates. These actions alone would be first steps in reducing sulfur and nitrogen emissions to the atmosphere and, thereby, in curing acid deposition. If an emission "cap" is used, we would suggest a maximum of five pounds of sulfur dioxide per million Btu initially, to be followed by four pounds of sulfur dioxide per million Btu within seven years. The average emissions would be smaller, initially reducing sulfur dioxide by about three million tons per year.

An alternative to the emission cap has been proposed in S1709, which was introduced by Mr. Moynihan. This bill would provide for about six to seven million tons per year of reduction in sulfur dioxide over and above what currently approved state SIP's would require. The total reduction of sulfur dioxide required by Mr. Moynihan's bill would be quite similar to those of S1706 (Mr. Mitchell), but those states which have done the best job towards meeting their SIP and those states which are already burning low sulfur fuels would benefit - as they should -from Mr. Moynihan's bill.

S1706 does not allow for any growth of sources without some trade-off taking place. This would be overly restrictive in those places, such as the Northeast, where we have diligently pursued reductions in sulfur dioxide since we do not have excess emissions to trade for new growth. S1709, on the other hand, seems to allow for such growth as long as NSPS is used.

We would, however, like to see a requirement that Best Available Control Technology be required for any new sources of sulfur dioxide, thus insuring that new emissions are as low as possible.

Another issue, but one which we must focus on, is regulatory reform and the potential for inconsistent regulations. While we all would like to see less red tape and bureaucratic tampering with our control programs, we do not want to see the federal government abrogate its role of protecting downwind states from the excesses of upwind states. The Clean Air Act of 1970 was passed because the 1967 Act did not accomplish its purpose. Many states failed to adopt air quality standards at that time, even though we in New York State did so.

We do not want to go through the same process and find that New York and the other Northeastern states will have to adopt stricter emission requirements to make up for the failure of other states which opt for no control or inadequate control. Congress must carefully balance regulatory reform with the need to protect the innocent.

We urge Congress to amend the Clean Air Act this year and to include provisions to control acid precipitation. We wish to thank the Committee for the opportunity to be heard, and we would be happy to provide any further information that we have available.

REFERENCES

1. Coffey, P.E.; Galvin, P.J.; Samson, P.J.; and Cline, J.A.; Summer Aerosol Transport Study, New York State Department of Environmental Conservation, AIR-P65, 1979.
2. Hilst, G.R.; Mueller, P.K.; Hidy, G.M.; Lavery, T.F.; and Watson, J.G.; EPRI Sulfate Regional Experiment: Results and Implications, EPRI EA-2077-SY-LD, 1981.

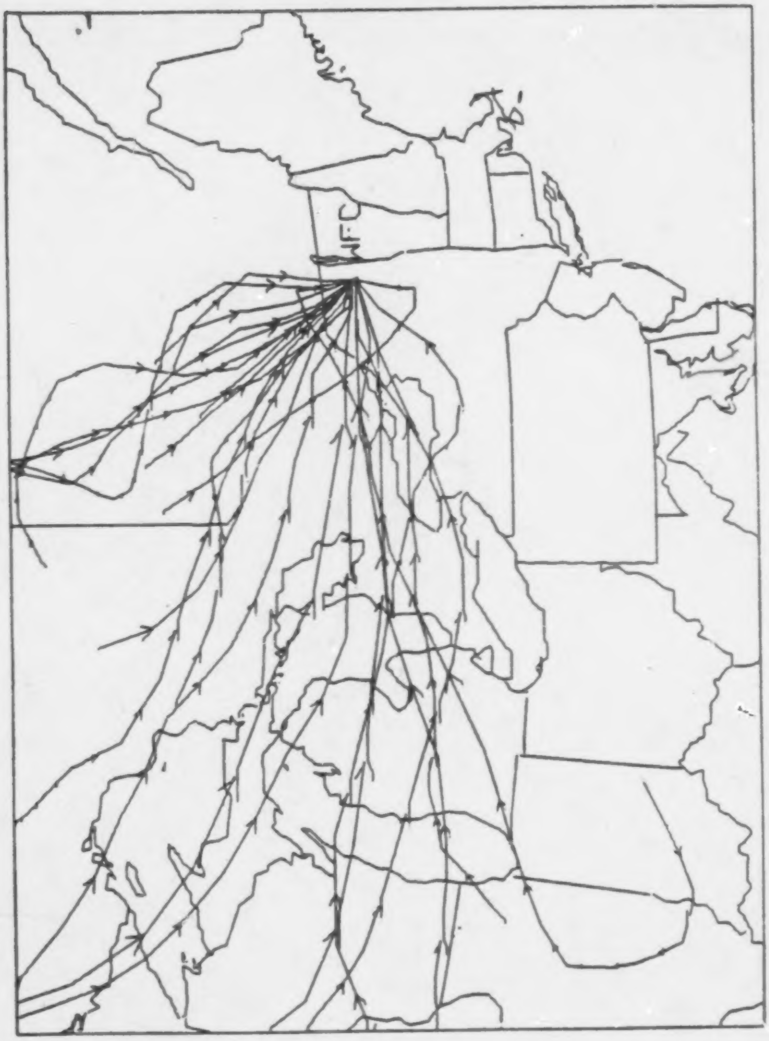


Figure 1.

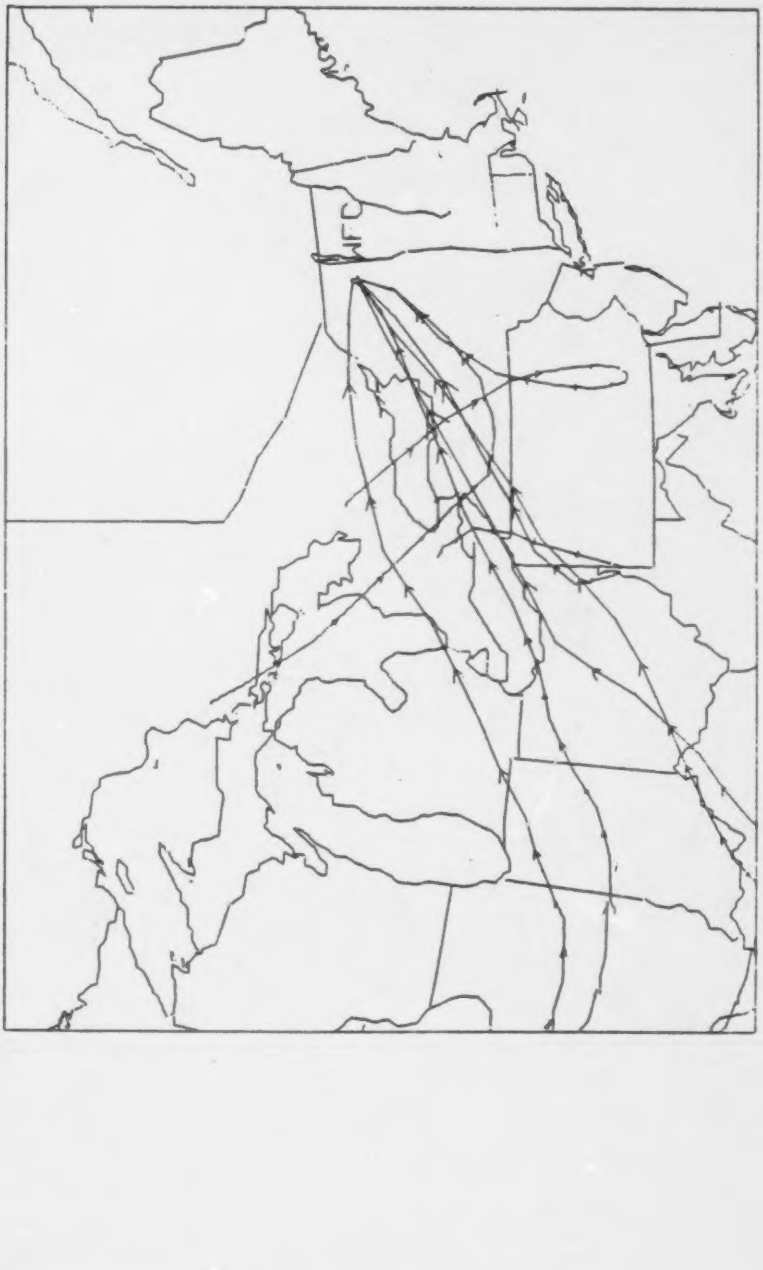
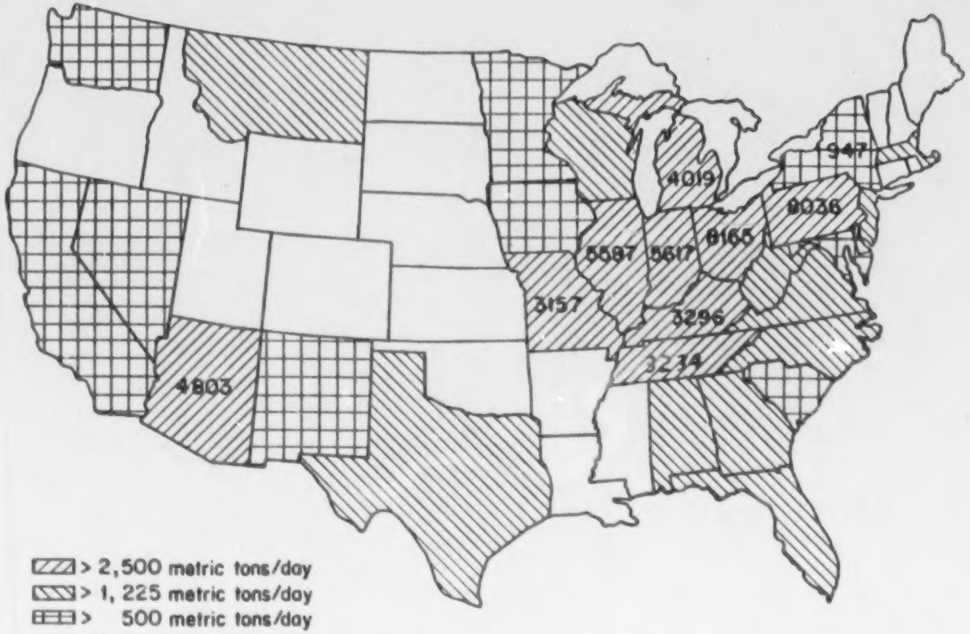


Figure 2.


947
4019
8036
8165
5587
5617
3157
3296
3234
4803
▨ > 2,500 metric tons/day
▨ > 1, 225 metric tons/day
▦ > 500 metric tons/day

"Emission of SO_2 in metric tons per day from U.S.E.P.A. 1974."

Figure 3.

Statement of

JOHN R. HOLMES, Ph.D.
Chief, Research Division
California Air Resources Board

Mr. Chairman and Members of the Committee:

I appreciate the opportunity to appear here before your Committee today to present some recently acquired scientific data on the nature and extent of acid precipitation in California. Even though we have begun only recently to study the problem intensively, there is still a substantial amount of information available. I don't propose to go through it all in my oral testimony. Instead, I will provide these documents to the staff so they can be entered into the record of this hearing.

In reviewing this material, I think you will find that the acid rain problem in California is, at once, both simpler and less well understood than it is in other parts of the country and the world.

A study carried out along the north coast of California in the early '70s demonstrated conclusively that rain storms arriving at the Pacific Coast in relatively clean areas have pHs in the normal range, well above 5. Chemical analysis shows these clean rainfalls contain only a trace of sulfuric acid and almost no nitric acid. So, acidification of our rain and snow is clearly going to be attributable to pollution we generate ourselves.

We have also known since the early '70s that the smoggy, foggy atmospheres of California's coastal cities such as Los Angeles have a unique ability to convert sulfur dioxide and nitrogen oxides to particulate sulfates and nitrates. These particles form an important part of the infamous brown L.A. haze that we have been trying so hard for so long to get rid of. We discovered later in the decade that these small suspended particles--aerosols--can be extremely acidic. This, in and of itself, presents a significant risk of harm to health--these acid particles are so small that they penetrate the defenses of the respiratory system and deposit in the deepest parts of the lung where they can cause irritation and damage to sensitive tissues. For this reason, in 1977, the State of California established an ambient air quality standard to limit community exposure to sulfuric acid and sulfate aerosols. With the knowledge that these acids are present in the atmosphere, we decided to move ahead with a program to sample precipitation in both northern California and the Los Angeles Basin. We were astounded by what the U.C. Berkeley and Caltech researchers who carried out this work found. Acid levels over a large portion of the state average ten to one hundred times the normal value. Maximal readings in the Los Angeles and San Jose areas were in the range of 500 to 1,000 times the normal value. These readings occurred at distances ranging from a few miles to a hundred or more miles from source areas; the levels of acidity are comparable to readings reported for the Northeast. The details are documented in the materials I have submitted for the record. One finding is so important, however, that I'd like to emphasize it for you, Mr. Chairman. As you know, the acidity of rain in the Eastern United States is attributed to sulfur and nitrogen oxides in the ratio of about two to one. In California, the situation is reversed: about two-thirds of the acidity is caused by nitrogen oxides and only about one-third by sulfur oxides. Most of these nitrogen oxides are emitted by cars. For this reason, as well as others, we're very concerned about the drive to weaken federal auto emission standards for nitrogen oxides. Any substantial change in these standards will make it extremely difficult for California and the other western states to deal with the acid rain problem. That's the simple part, we pollute our own rain. So we can, if we need to and want to, clean it up.

The question that remains is, do we need to, and if so, to what extent. The answer has only begun to emerge. We are carrying out studies now to determine the sensitivity of lakes, soils and crops in California to damage from acid rain and acid snow. Areas in the Sierra Nevada, the experts tell us, may be extremely sensitive to even minute amounts of acid--because they have such a low capacity to neutralize or buffer strong acids like sulfuric and nitric. Data we have recently acquired confirm this. The alkalinity (as measured by available calcium) of 170 Sierra Nevada lakes studied is among the lowest in the world.. Although their current pH averages just under 6, they have essentially zero capacity to absorb additional acid inputs without moving into the range at which fish will be unable to reproduce and survive.

The only data we have that show long-term trends in acidity is for reservoirs. The vast Hetch-Hetchy reservoir in the central Sierra supplies water to the city of San Francisco. Its acidity has doubled over the last 25 years, indicating that the smaller lakes and streams that supply it are becoming acidic with alarming rapidity. Where are these smaller lakes and streams? In Yosemite National Park, the crown jewel of our National Park System and one of the most beautiful and highly valued recreational resources in the nation.

Soil chemists tell us that marginal soils in the Sierra foothills and elsewhere--currently of immense value to the forest products industry and to the livestock industry for grazing and summer pasture--may also lose some or all of their productivity over a period of years if acid rain continues to fall and remove mineral nutrients from the thin layer of soil.

Everyone agrees that we will need to do more research to determine how much acidity these aquatic ecosystems and soils can absorb without showing adverse effects. But while these studies are underway, we are at the same time implementing control measures for sulfur and nitrogen oxides that will limit acid deposition in this decade.

Most power plants in California are now required to burn either natural gas or specially refined low-sulfur fuel oil. Sulfuric acid plants and sulfur recovery units in refineries are stringently controlled. The State has adopted regulations that limit the sulfur content of gasoline and diesel fuel. Our auto emission standards for nitrogen oxides are the lowest in the nation. Even so, ambient levels of NOx aren't changing significantly, so we're moving to further reduce NOx emissions from stationary sources as well--power plants, oil refineries and other large users of fossil fuels.

To summarize then, our knowledge of acid rain and its effects in California is admittedly less complete than it is here in the East. But we are certain that strongly acidic rain is falling there now, and that it results from our own emissions of acid precursors--not from those of another state or another nation. We know that it's dominated by nitrogen rather than sulfur oxides. And we're moving ahead now with control measures that will reduce emissions of these precursors, with heavy emphasis on NOx.

It seems to me that because this problem is so insidious--it's a problem that can develop slowly, almost unnoticed, over years or decades and then manifest itself almost overnight as the death of dozens or hundreds of lakes and streams, or as a rapid drop in the productivity of hitherto fertile field or forest--that action is called for now, not later. We in California feel very strongly that the Congress must take the lead in encouraging and requiring the States to do everything we can to avoid any further increase in the acidity of rain and snow falling on California and the rest of the nation. And we need to move as quickly as is practicable to reverse what appears to us to be a disturbing trend. With the prospect of even more widespread irreversible damage to our forests, agricultural lands, lakes and streams, to do otherwise would, I think, be utterly irresponsible.

SUPPLEMENTAL TESTIMONY

JOHN R. HOLMES, Ph.D.
California Air Resources Board

Some scientists have claimed that acid rain containing nitrates would not acidify soil. They postulate that soil bacteria would reduce the deposited nitrate to nitrogen gas, producing hydroxide ions which would neutralize the acidity associated with the nitrates. This process may well occur in certain soils but bacteria should not be expected to neutralize acid deposited on most soils, especially not those mountain soils potentially very sensitive to the detrimental effects of acid rain, for a number of reasons. In any event, soil bacteria can do nothing to mitigate the direct impact of nitric acid on aquatic ecosystems or plants.

To begin with, several factors inhibit the bacteria's ability to convert nitrate to other products such as nitrogen gas and thus produce hydroxide ions.(1)

- Plants absorb and use nitrate so plants compete with bacteria for the available nitrate. Plants cannot use or absorb the acidic hydrogen of nitric acid. It remains in the soil.

- Most soils are well aerated and the presence of oxygen prevents the bacteria from converting nitrate to nitrogen gas.

- Most sensitive soils contain little organic matter. The bacteria need organic matter for food to provide energy to convert nitrate.

- Most soils potentially sensitive to acid rain have pH values below 6.5. Soil pH values below 6.5 can also limit the conversion process.(2)

- Temperatures below about 40°F limit the conversion process. When snow containing nitrates melts in the spring, the low temperatures would prevent the action of bacteria on the nitrate.

Because the soils are such complex systems, other factors will also neutralize hydroxide ions produced during the conversion of nitrate to nitrogen gas. For example, some soil bacteria convert nitrogen gas to nitrates. Acidity produced by these processes normally neutralizes all of the hydroxide ions produced by the other organisms during the conversion of nitrate to nitrogen gas.(3) Also, some soil bacteria in the presence of sulfur, a constituent of the soil and acid rain even in California, actually produce additional acids which further acidify the soil.(1)

In summary, the evidence suggests that it seems unlikely that natural soil processes often neutralize nitric acid in rain.

In fact, field measurements by Norton(2) indicate that acid rain occurring in the northeastern United States is acidifying soil and leaching essential plant nutrients and toxic elements from soil. These detrimental effects should generally be viewed with great concern.

(1) Alexander, Martin, Introduction to Soil Microbiology, 2nd edit., John Wiley & Sons, New York, p. 467. 1977.

(2) Norton, S. A., "Changing Processes in Soils Caused by Atmospheric Deposition of Pollutants", In: California Symposium On Acid Precipitation, (D. Lawson and J. Holmes, eds.), California Air Resources Board, pp. 148-163. October 1981 (in press).

(3) Schroeder, E. D., "Denitrification in Wastewater Management", In: Denitrification, Nitrification and Atmospheric Nitrous Oxide, (C. C. Delwiche, ed.), pp. 105-125. University of California Press, Berkeley. 1981.

TESTIMONY OF
ATTORNEY GENERAL JAMES E. TIERNEY
STATE OF MAINE

SENATOR STAFFORD, MEMBERS OF THE COMMITTEE.

MY NAME IS JAMES TIERNEY. I AM THE ATTORNEY GENERAL OF THE STATE OF MAINE. I SPEAK TODAY ON MY BEHALF AND ON BEHALF OF THE ATTORNEYS GENERAL OF NEW HAMPSHIRE, VERMONT, MASSACHUSETTS, RHODE ISLAND, CONNECTICUT, NEW YORK, AND NEW JERSEY WHO HAVE ENDORSED THE LEGISLATION BEFORE YOU THIS MORNING. I ALSO SPEAK ON BEHALF OF GOVERNOR JOSEPH E. BRENNAN AND, MOST IMPORTANT, ON BEHALF OF THE PEOPLE OF THE STATE OF MAINE.

AS RECENTLY CERTIFIED BY THE NATIONAL ACADEMY OF SCIENCES, THERE IS NO REASONABLE SCIENTIFIC DISPUTE AS TO SEVERAL BASIC FACTS:

1) THERE ARE SEVERAL KINDS OF AIR POLLUTION IN GASEOUS FORM OR AS FINE PARTICLES, THAT ARE CARRIED LONG DISTANCES FROM THEIR POINT OF EMISSION.

2) THOSE SAME POLLUTANTS ARE CHEMICALLY TRANSFORMED WHILE AIRBORNE IN ASSORTED COMPLEX REACTIONS TO BECOME DIFFERENT POLLUTANTS ENTIRELY, FROM THOSE EMITTED DIRECTLY FROM ANY SOURCE.

3) AS A RESULT OF SCIENTIFIC RESEARCH DONE BY THE MOST DISPASSIONATE OBSERVERS, THE PRESENCE AND EFFECTS DOWNWIND OF THESE SECONDARY POLLUTANTS CAN BE MORE AND MORE RELIABLY PREDICTED.

4) ENVIRONMENTAL EFFECTS OF THESE POLLUTANTS HAVE ALREADY HAD SERIOUS ADVERSE ENVIRONMENTAL IMPACT ON MY STATE AND ON THE NORTHEAST, AND THE CLEAR TREND IS THAT THESE EFFECTS ARE INCREASING AS THE EMISSIONS INCREASE. ACID RAIN AND INTERSTATE AIR POLLUTION NOW POSE THE NUMBER ONE DANGER TO THE NATURAL ENVIRONMENT OF MY STATE.

I NEED NOT REMIND THIS COMMITTEE OF THE COMMENDABLE EFFORTS OF THE CONGRESS TO FIGHT AIR AND WATER POLLUTION IN THE LAST TWO DECADES. THANKS TO THE EFFORTS OF MANY PEOPLE IN THIS ROOM AND IN PARTICULAR THE EFFORTS OF MAINE'S FORMER SENATOR EDMUND S. MUSKIE, OUR NATION HAS TAKEN SIGNIFICANT STEPS TO PRESERVE THE PHYSICAL ENVIRONMENT IN WHICH WE LIVE. LITERALLY BILLIONS OF DOLLARS HAVE BEEN SPENT BY OUR FEDERAL GOVERNMENT AND BY PRIVATE INDUSTRY TOWARD THAT END. THOSE WHOSE HEALTH DEPENDS ON CLEAN AIR, OR WHOSE LIVELIHOOD DEPENDS ON OUR LAND OR WATERS, WOULD TELL YOU TODAY THAT WE ARE A HEALTHIER AND MORE PROSPEROUS NATION AS A RESULT.

MAINE PEOPLE HAVE ALWAYS TREASURED THEIR ENVIRONMENT. MANY OF YOU WHO HAVE TRAVELED TO MY BEAUTIFUL STATE HAVE ENJOYED THE CLEAN LAKES AND STREAMS, THE FRESH AIR AND OUR SPECTACULAR COAST. WHAT YOU MAY NOT HAVE SEEN IS ~~THAT BEHIND~~ THAT BEAUTY IS THE DEEP DEDICATION OF ALL OUR CITIZENS, INDIVIDUAL AND CORPORATE ALIKE, TOWARD PRESERVING AND DEFENDING THAT ENVIRONMENT.

LIFE IS NOT EASY IN OUR STATE. MANY OF OUR PEOPLE ARE ELDERLY POOR. WE ARE REMOTE FROM AMERICA'S ECONOMIC MAINSTREAM. THE WINTERS ARE LONG AND THE GROWING SEASONS ARE SHORT, BUT A MILLION OF US HAVE DECIDED THAT MAINE IS WHERE WE WANT TO RAISE OUR FAMILIES, LEAD OUR PROFESSIONAL LIVES, AND LOOK FORWARD TO A LONG AND HAPPY RETIREMENT. THE PEOPLE OF MY STATE HAVE OFTEN TIMES MADE SIGNIFICANT FINANCIAL SACRIFICES IN THAT DECISION BUT WE HAVE DONE SO WILLINGLY. FIRST, BECAUSE OF THE QUALITY OF OUR NEIGHBORS AND SECOND, BECAUSE OF THE QUALITY OF OUR NATURAL ENVIRONMENT.

THE FRUSTRATION OF OUR CITIZENS FACING THE ACID RAIN PROBLEM IS NOW GROWING TO ANGER. DESPITE OUR YEARS OF WORK AND SACRIFICE, WE SIT FEELING HELPLESS AS THE RAIN FALLS AND WE MUST WATCH OUR FISH DIE AND SEE OUR PRIMARY ECONOMIC RESOURCES OF FORESTRY AND AGRICULTURE THREATENED THROUGH THE POLLUTANTS BROUGHT TO US FROM OTHER STATES. WE FIND NOW THAT THE GROWTH OF OUR OWN INDUSTRIES WILL BE CHOKED BECAUSE POLLUTION COMES TO US FROM OTHER STATES IN SUCH QUANTITIES THAT MUCH AIR QUALITY RESERVED FOR MAINE INDUSTRIAL EXPANSION IS ALREADY TAKEN.

IN 1977, ON THE BASIS OF MUCH LESS COMPLETE SCIENTIFIC KNOWLEDGE, CONGRESS RECOGNIZED THE PROBLEM OF INTERSTATE AIR POLLUTION, AND THE NEED FOR AN ACTIVE FEDERAL ROLE TO CONTROL IT. IN THE LAST REAUTHORIZATION OF THE ACT, NEW PROVISIONS WERE ADDED TO ENABLE EFFECTED STATES TO OBTAIN RELIEF.

IN SPITE OF THESE NEW SECTIONS, THE UPWIND STATES HAVE MADE NO EFFORT TO CARRY OUT THEIR RESPONSIBILITY OF ANALYZING THEIR OWN PART IN POLLUTING DOWNWIND STATES. THE E.P.A. HAS NOT STEPPED IN TO SEE THAT THE JOB IS DONE. ON THE CONTRARY, MANY HAVE ASKED TO INCREASE THEIR EMISSIONS SUBSTANTIALLY, AND THE E.P.A. HAS APPROVED THE INCREASES WITHOUT THE BAREST EFFORT TO DETERMINE THEIR INSTATE IMPACT.

SENATOR GEORGE MITCHELL, WITH BIPARTISAN SUPPORT, HAS PRESENTED FOR YOUR CONSIDERATION A BILL WHICH WILL FIRST, STOP THE PROBLEM FROM GETTING ANY WORSE, AND THEN, OVER THE NEXT DECADE, REDUCE THE PRECIPITATING EMISSIONS BY 40%. UNDER THE BILL, THE BURDEN OF THESE EMISSION REDUCTIONS WILL BE SPREAD AMONG THE EASTERN STATES IN THE SAME PROPORTION THAT THE SOURCES OF THE HIGH EMISSIONS ARE NOW DISTRIBUTED. THE PROBLEM IS REAL, AND SENATOR MITCHELL'S SOLUTION IS EQUITABLE.

IT MAY NOT BE ENOUGH; ONLY TIME AND FURTHER MONITORING WILL TELL.

THE ATTORNEYS GENERAL OF THE EASTERN STATES KNOW OF WHAT WE SPEAK. WE HAVE SINCE TRIED TO USE THE 1977 PROVISIONS TO GAIN RELIEF BUT TO NO AVAIL. LAWSUITS AND ADMINISTRATIVE PETITIONS HAVE GAINED US NOTHING AND COST US TIME. A STRONGER CONGRESSIONAL MANDATE IS NEEDED. SENATOR MITCHELL'S BILL WILL DO MUCH TO STOP ACID RAIN BUT OTHER PROVISIONS OF THE ACT SHOULD ALSO BE STRENGTHENED IF THE ACT IS TO PROVIDE AN EFFECTIVE METHOD OF ADJUSTING INTERSTATE AIR POLLUTION DISPUTES AND, EVENTUALLY, PREVENTING THEIR OCCURRENCE. THE ATTORNEYS GENERAL OF

THE EIGHT STATES FROM NEW JERSEY TO MAINE JOIN IN COMMENDING YOUR ATTENTION TO A SET OF PROPOSED AMENDMENTS TO ACCOMPLISH JUST THAT. I ASSURE YOU THEY ARE BORNE OF EXPERIENCE.

I AM NOT INSENSITIVE TO THE DIFFICULTIES FACING THE INDUSTRIES IN THE MIDWESTERN PART OF THE UNITED STATES. I UNDERSTAND THE TREMENDOUS COMPETITION THEY ARE UNDER FROM FOREIGN MARKETS. I UNDERSTAND THAT MANY OF THEIR FACILITIES ARE OUTMODED AND THAT EVEN MODEST INCREASES IN THE COST OF POWER WILL LOOM LARGE. I UNDERSTAND TOO THE DIFFICULTIES THE UTILITIES OF THIS COUNTRY ARE FACING AS A RESULT OF THEIR UNDERESTIMATION OF AMERICA'S ABILITY TO CONSERVE.

BUT MAINE PEOPLE HAVE ALREADY DONE MUCH, AND WILL CONTINUE TO DO EVERYTHING WE CAN TO SOLVE OUR OWN PROBLEMS. WE DO NOT COME TO WASHINGTON EASILY FOR HELP. IT IS WITH JUSTIFICATION THAT WE ARE KNOWN AS SELF-RELIANT AND INDEPENDENT. MAINE LEADS THE NATION IN THE CONSERVATION OF ENERGY, AND BECAME THE FIRST STATE IN THIS COUNTRY TO HAVE WOOD AS ITS PRIMARY SOURCE OF RESIDENTIAL HEAT. ELECTRIC POWER DEMAND IN MAINE HAS DECLINED FASTER THAN THE MOST OPTIMISTIC PROJECTIONS. OUR MANY PULP AND PAPER MILLS HAVE CHANGED THEIR MANUFACTURING PROCESSES AND INCORPORATED MODERN POLLUTION CONTROL INTO THEIR BASIC DESIGN. AIR POLLUTION LIMITS HAVE BEEN STRICTLY SET. THE PUBLIC PRESSURE TO MEET THEM IS GREAT, AND COMPLIANCE HAS BEEN NEARLY TOTAL. BUT IN THE RACE OF INTERSTATE AIR POLLUTION, THE PEOPLE OF MAINE CAN ONLY TURN TO THIS CONGRESS FOR ASSISTANCE. THERE IS NO ONE ELSE.

THERE IS NO DOUBT THAT A BALANCE MUST BE STRUCK, BUT THAT BALANCE CANNOT BE AT A POINT THAT ALLOWS THE IRREVERSIBLE DESTRUCTION OF THE ENVIRONMENT OF MY STATE.

STATEMENT OF WILLIAM HINKLEY, ENVIRONMENTAL ADMINISTRATOR, DEPARTMENT OF ENVIRONMENTAL REGULATION, STATE OF FLORIDA

Mr. Chairman and members of the Committee, I am William Hinkley, here on behalf of the Florida Department of Environmental Regulation, to provide you with information on acid rain in Florida and comments on legislative proposals for the control of acid rain. We greatly appreciate the opportunity to address you on this important issue. However, in the limited time which we have had available, we have not been able to prepare detailed comments on the proposed legislation and its potential impacts on Florida. Additionally, to be frank, we are not as well informed on the matter of acid rain as we should be, nor do we have the experience and knowledge of the more heavily impacted northeastern states. At the same time, Florida is included in the acid rain control region contemplated in both S. 1706 and S. 1709, and therefore we believe it is important that the Committee be aware of what is, and is not, known about the problem in Florida. Following this brief overview, we will provide general comments on the proposals to control acid rain.

Relative to the northeastern United States, Canada and northern Europe, the study of acid rain and its impacts in Florida is in its early stages. The most definitive studies to date have been those conducted by Dr. P.L. Brezonik (now with the University of Minnesota) and his colleagues at the University of Florida (Brezonik, Edgerton and Hendry, 1980; Hendry and Brezonik, 1980). Based on data collected during 1976-79, these investigators have found that annual average pH values below 4.7 now occur over the northern three quarters of the state. The acidity of rainfall gradually diminishes southward down the Peninsula until near Lake Okeechobee, near normal rainfall pH values (5.6) are observed. The lowest pH value recorded in a bulk precipitation sample was at Jay, Florida, in the Panhandle, and was 3.76. The two most acidic rainfall events in Gainesville had a pH of 3.93. The degree of acidity of Florida rainfall is not as great as that reported for the Northeast United States. However, due to Florida's high rainfall (about 55 inches/year or 50-75% greater than the Northeast), the annual deposition of H+ ions in northern Florida is estimated to be as much as a third to a half the deposition in the Northeast. Historical pH data are lacking for Florida rainfall, but ionic balance analyses of rainfall data collected at five sites during the mid-1950's indicate that the pH values of rainfall at those sites were above 5.6 during this time period. In addition, the deposition of sulfate ions has increased almost four-fold from the 1950's. Assuming that contributions of sulfur from the ocean and biogenic sources have remained relatively constant since the 1950's, the University of Florida investigators conclude that the increase must be due to anthropogenic sources. Sulfuric acid and nitric acid account for nearly all of the acidity of Florida rainfall, with sulfuric acid making up more than two-thirds of the total.

The sources of the precursors for acid rain in Florida can only be inferred at this time. Presently, about one million tons of SO_2 are being emitted in Florida. Nearly all of these emissions are from fossil fuel sources, and about 70% are from electric generating plants. Twenty-five percent are from industry and 7% are from mobile sources. In contrast, with respect to nitrogen oxide emissions, 60% are from mobile sources, 25% are from electric generating plants and 15% are from industry (Florida Sulfur Oxides Study, Inc., 1978). Brezonik and his co-workers found that summer (May-October) rainfall was more acidic (0.2 to 0.3 pH units lower) than winter (November-April) rainfall.

They speculate that this may be due to the greater efficiency of turbulent summer convective showers in scavenging acid precursors as compared to winter frontal events. However, they also note that this may reflect the higher rates of electric power generation which occur in Florida in the summer. On a yearly basis, Florida utilities experience both winter and summer peak demand, but the total electricity generated in the summer is higher due to heavy air conditioning use (Florida Electric Power Coordinating Group, 1980). Because rainfall acidity and sulfate deposition are both lower in the winter months when northern frontal activity occurs, there has been further speculation that contributions of sulfuric acid precursors from out-of-state sources are not as important as in-state contributions. On the other hand, it is known that parts of Florida experience a number of pollution episodes each year of several days duration each, where as much as 80% of the total pollutant load is attributable to relatively remote Middlewest sources. The net contribution of these long-range transports of pollutants to Florida's acid rain is unknown. Another unknown factor is to what extent, if any, Florida generated acid precursors are transported to other states. Becuase of the prevailing winds and other meterological factors, our best estimate is that, at maximum, 5-10% of Florida-generated SO_2 is transported north or west to other states.

It should be noted that to better determine the sources of acid rain in Florida, the Florida Electric Power Coordinating Group, Inc. (1981) has recently initiated a major study of the distribution and loadings of acid rain in the state. An extensive monitoring network has been established and source attribution and long-range transport analyses will be conducted. This study is being funded at a high level and should provide us with a much better understanding of the transport of acid rain precursors both within and in and out of the state.

Little is presently known about the ecological effects of acid rain in Florida. Until recently, the prevailing view has been that water bodies in regions like Florida that are underlain by limestone have naturally high buffering capability and are relatively insensitive to acid rain. In Florida, sinkhole lakes in direct contact with the limestone Floridian Aquifer, or waterbodies which receive alkalinity inputs from runoff, fall in this category. However, there are many softwater lakes in the state, along the Central Highlands Ridge and in the Panhandle, which are perched in leached Pleistocene sandy soils, are well above limestone deposits and are susceptible. Chrisman, et. al. (1980) and Crisman and Brezonik (1980) report on a study of thirteen such poorly buffered lakes in North Florida which receive acid rain, and seven comparable lakes in South Florida near the southernmost boundary of acidic rainfall. Comparison of present data to that of the past 20 years indicates that pH values of the northern lakes have declined an average of 0.5 pH units since 1960; sulfate concentrations have increased and alkalinity present in the 1960's has been completely titrated. In contrast, there was no change in the southern lakes. These reports also note that distinct changes were also seen in aquatic ecosystems in the northern lakes, including decreases in chlorophyl a levels, changes in phytoplankton populations and a general reduction in both biomass and species richness. In contrast to acidified lakes in the Northeast,however, impacts on sport fishes seem minimal.

The Florida Department of Environmental Regulation in 1980 conducted a preliminary analysis of the potential impacts of acid rain in Florida on lakes, aquatic biota and soils. Utilizing the pH/alkalinity relationship expressed by Glass for the

Boundary Waters Canoe Area - Voyaguers National Park (Glass, et. al. 1980), 100 Florida lakes were analyzed to determine a first approximation of buffering capability. Thirty-eight lakes fell in the "susceptible" range and 21 fell in the "potentially susceptible" range. With regard to soils, an examination of the cation exchange capability (CEC) and percent base saturation of a representative group of Florida soils suggests that most soils, especially those used most heavily for agriculture, have high buffering capability. On the other hand, highly leached, sandy soils typical of many environmentally unique areas in Florida, have low buffering capability and are clearly susceptible to acid rain. There is no clear picture of how Florida aquatic organisms are being impacted by acid rain. Despite the state's limestone and karst geology, many rivers, lakes and streams in Florida are naturally highly acidic. For example, the Suwannee River typically has pH values of 3.5 - 4.2 near its source at the Okeefenokee Swamp, yet it supports healthy populations of sport fishes. In addition, pH in a given stream can change dramatically over relatively short distances, as swamp drainage is diluted with groundwater baseflow. Again, looking at the Suwannee, (a near pristine system), by the time the river reaches a point 100 miles downstream, the pH has doubled.

To summarize the acid rain situation in Florida, we know we've got it,but we don't know fully what its doing to us. some evidence suggests stress to aquatic ecosystems yet nothing like sterilization of lakes such as is occuring in the Northeast is happening in Florida to our knowledge.

With this background, we would like to offer the following comments on the legislative proposals being considered by the Committee to control acid rain. In general, Florida supports the positions of the National Commission on Air Quality and the National Governors' Association on the control of acid rain, and it appears that these positions are incorporated into S. 1706 and S. 1709.

1) Clarification of federal acid rain control and coal conversion policies

Florida's primary concern regarding these legislative proposals is the apparent conflict between the control of acid rain and coal conversion. The relationship between these two national ovjectives needs to be clarified by Congress. Neither S. 1706 nor S. 1709 address the issue. Partially in response to earlier federal initiatives, Florida has been aggressively pursuing coal conversion. The first coal-oil mixture test burn has recently been conducted in Florida, and plans are currently underway to convert an estimated 10,000-12,000 megawatts of capacity from oil to coal. This represents about 40 - 50% of the net state capacity. Florida has an extraordinary dependence on oil for electric power generation: 47% of the state's total capacity is oil-dependent vs. only 15% nationally. In that the states are now negotiating coal conversion procedures with utilities, the requirements for acid rain controls need to be integrated into the process.

2) Allowances for growth when NSPS are met

S. 1706 appears to make no allowances for new capacity without first identifying reductions elsewhere, even if New Source Performance Standards (NSPS) are to be met. S. 1709 exempts new plants which meet NSPS. During the period

1970-1980, Florida's population increased by an astounding 43%, the third fastest growth rate in the country. By the year 2010, Florida's population is expected to double to almost 17 million people. Approximately ten new electric generating plants are proposed for the next decade, all coal-fired and all anticipated to meet NSPS.

3) Consideration of sub-regional variations in emission reduction criteria

We have some concern that having a single emission reduction criterion for all of the 31-state region identified in both S. 1706 and S. 1709 fails to take into account differences within the region regarding acid rain, characteristics and distribution. As described above, the acid rain situation in Florida has many similarities to that of the Northeast, but also some important differences, particularly in regard to interstate transport. We would urge the Committee to consider the possibility of creating several regions with different criteria or to otherwise allow for regional variations.

4) Targeting major reductions for worst problem areas

We concur with the intent in S. 1709, but how it defines major sources, to require the most cleanup of the worst problem areas.

5) Additions to emission reduction programs

The list of enforceable emission reduction programs in S. 1706 could be improved by allowing investments in co-generation, time-of-day pricing and non-emitting alternative, renewable energy sources as well as energy conservation where it can be shown that such investments will reduce emissions.

6) Funding provisions

Adequatic funding for both state agencies and the EPA will be necessary to ensure that the emission reduction programs are workable, enforceable and cost-effective. We are particularly concerned over EPA's ability to handle this major new responsibility in the face of rumored drastic budget cutbacks.

Definitions of "Major Sources"

By concentration on SO_2 emission rates and total tonnage of SO_2 emitted, both S. 1706 and S. 1709 fail account for stack height. Plants in some areas with high stacks may be more of a concern for acid rain formation, even though they are below the threshold for major sources.

8) Federal funding and support for further research

While not a specific concern of these legislative proposals, we hope that a vigorous federal acid rain research program will continue even as controls are implemented. In Florida, far more is unknown about acid rain than is known, and we are in great need for continued federal funding and support for research.

thank you, Mr. Chairman, for the opportunity to present this information the Committee and hope that it proves useful as you deliberate on this most mplex and challenging issue.

References Cited

Brezonik, P.L., E.S. Edgerton and C.D. Hendry. 1980. Acid Precipitation and Sulfate Deposition in Florida. Science, Vol. 208, May 30.

Crisman, T.L. and P.L. Brezonik, 1980. Acid Rain: Threat to Sensitive Aquatic Ecosystems. Paper presented to the 73rd Annual Meeting of the Air Pollution Control Association. Montreal, Quebec.

Crisman, T.L.,et. al. 1980, Acid Precipitation: the Biotic Response in Florida Lakes. Paper submitted to the International Conference on the Ecological Impact of Acid Precipitation, Norway.

Florida Department of Environmental Regulation. 1980. A Preliminary Analysis of Acid Precipitation in Florida and Potential Impacts of Increased Coal-burning for Electric Power Generation. Florida DER, Tallahassee, Florida.

Florida Electric Power Coordinating Group, Inc. 1980. 1980 Florida Electric Power Plant Ten Year Site Plan.

Florida Electric Power Coordinating Group, Inc. 1980. Florida Acid Precipitation Study. ESE No. 80-610-600. Doc. No. D002. Environmental Science and Engineering, Inc. Gainesville, Florida.

Florida Sulfer Oxides Study, Inc. 1978. Florida Sulfur Oxides Study Final Report.

Glass, Norman R., et. al. 1979. Effects of Acid Precipitation. Env. Sci. Tech. 13:11, November.

Hendry, Charles D. and P.L. Brezonik. 1980. Chemistry of Precipitation at Gainesville, Florida. Env. Sci. Tech., 14:7 July.

WISCONSIN DEPARTMENT OF NATURAL RESOURCES ACID RAIN TESTIMONY
COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS
OCTOBER 29, 1981

My name is Bob Martini. I am an environmental specialist with the State of Wisconsin, Department of Natural Resources in Rhinelander, Wisconsin.

I am here to provide testimony on the potential impacts of acid rain on Wisconsin and on the adequacy of bills recently introduced in the Senate which are intended to control acid deposition and interstate transport of pollutants.

I would like to divide my testimony into the following four parts:

I. An assessment of the susceptibility of Wisconsin's resources to acidification damage and current acid deposition trends in Wisconsin.

II. A description of the research program we have established in Wisconsin to study the short and long term effects of acid deposition.

III. The Wisconsin Department of Natural Resources Board policy on acid deposition.

IV. Comments on S. 1709, S. 1706, and S. 1718.

V. The Wisconsin Department of Natural Resources has been actively involved in assessment of susceptibility of our state's resources to acidification since June, 1979. In the past 2½ years we have cooperated with over a dozen federal, state and local agencies in the study of acid deposition and its potential effects. I presented our estimates of the economic and environmental impacts of acid rain to the Senate Environment and Public Works Committee at the September 1980, hearings on the economic impacts of acid rain. We are especially concerned about acidification of our northern lakes which are the base of Wisconsin's $5 billion per year tourist industry.

To summarize our assessment of Wisconsin's aquatic susceptibility I would like to quote from an article, based in part on data we collected in northern Wisconsin, in Environment International by Norman R. Glass, Gary E. Glass (of EPA's Corvallis and Duluth laboratories respectively) and Peter J. Rennie of Environment Canada titled: "Effects of Acid Precipitation in North America":

> Watershed Sensitivity--Lakes and Streams
>
> As more coal-fired electric generating plants are built and become operational, especially in areas that are "upwind" in the airshed of the west-central United States, the Midwest, and the Southeast, the quantities of acid forming substances will exceed the acid-neutralizing assimilative capacities of watersheds and the processes of lake and stream acidification in many pristine areas of North America will be exceeded. The beginning point or "threshold" value for this process for Swedish lakes has been determined to be where the quantities of acids in the atmosphere cause the annual average pH of precipi-

tation to be depressed to 4.6, a value which corresponds to a hydrogen iron concentration ten times that of natural rain (Wright, 1976). Increased acid doses beyond the "threshold" value have resulted in the acidification of more than 15,000 lakes in Sweden and Norway, most to extreme acid levels where all fish have become extinct.

The transferability of data from Scandinavian observations to North American watershed's responses to acidified precipitation that interact with acids and related components will depend on the similarity of the environmental factors of the watersheds, and primarily on the lack of acid neutralizing (or alkaline) soils. This predominant factor places limits on the geographic regions where watersheds are susceptible to damage from acid precipitation. Lakes in the Adirondack State Park of New York, the Boundary Waters Canoe Area-Voyageurs National Forest and areas of northern Wisconsin are examples of such susceptible environments in the U.S. In the Adirondack area of New York State the "threshold" acid precipitation value has been exceeded for several years and as a result, lake pH values are depressed to the point where fish have stopped reproducing and some 100 lakes are now fishless (Schofield, 1976). Portions of eastern Canada have similarly been receiving acid deposition which exceeds the pH 4.6 threshold which results in fishless lakes (Beamish, 1976).

In northern Minnesota and Wisconsin, the process of lake acidification is just beginning and only the most susceptible lakes are being affected. This area is one that exhibits the properties of maximum sensitivity to acidification due to extremely soft water, thin and sandy soils, and very sensitive terrestrial and aquatic plants and animals. In addition, the BWCA-VNP is a wilderness area where the U.S. Congress has taken extreme care to preserve the environment against the impacts of pollution and no man-induced changes are desired.

The northern Minnesota and Wisconsin region, like the Adirondack Park area, is found on acidic bedrock which is the main criterion for an acid-sensitive classification. Of the midwestern states, only upper Michigan, northern Wisconsin, and northern Minnesota have this type of bedrock covering wide areas (Likens et al., 1979). The northern Wisconsin lakes are located in areas of sandy acidic soils and this factor makes them especially acid sensitive (Fig. 1). The lakes in northern Minnesota and Wisconsin have been surveyed only recently for possible impacts from acid precipitation (Glass and Loucks, 1980). About two-thirds of the 455 lakes sampled in 1979 are susceptible or potentially susceptible to change from acid precipitation using the criteria suggested by Kramer (1976). If these lakes are representative of about 20,000 lakes in this region, then the potential for severe ecological damage is serious. The annual average pH of precipitation in this region is approximately 4.6 and contributions from increasing emissions, including major coal-fired power plants being built or just completed in the area, will certainly increase the concentrations of acids being added to susceptible watersheds and increase the rate of stream and lake acidification. A larger percentage of lakes in northern Wisconsin are on the verge of acidification and may be receiving higher doses than lakes in northern Minnesota due to their proximity to sources. The potential for adverse effect of acid precipitation is higher because the assimilative capacity has been depleted.

Various fish species have dissimilar responses to different levels of lake pH (Beamish, 1976). Figure 1 includes a partial listing of fish species that are vulnerable showing this dissimilarity in reproductive interference at selected pH ranges. Of the 350 Wisconsin lakes sampled in 1979, 13% were in the pH range where other investigators have found interference to fish reproduction.

Figure 2 (pH of Precipitation in northern Wisconsin -1980) shows the pH of rainfall events measured in northern Wisconsin during calendar year 1980 by Wisconsin Department of Natural Resources, North Central District. The 1980 volume weighted annual mean pH of precipitation in northern Wisconsin was 4.4; more than ten times as acid as normal precipitation (Normal is defined here as 5.6 pH, the equilibrium point of CO_2 in water). (Figure 3 shows the location of acid deposition samplers for the data on Figure 2.)

In 1981 the mean pH of precipitation in northern Wisconsin is still approximately ten times as acid as normal and the total sulfate loading is approximately 20 kg/ha per year. The threshold for acidification damage to aquatic ecosystems has been determined to be approximately 10 kg/ha/yr in Scandinavia and areas of the eastern North American continent.

Documentation for this damage threshold loading rate and calculations of cutbacks in SO_2 NO_x necessary to reduce total wet and dry loadings in the eastern United States to 10 kg/ha/yr are contained in the "U.S.-Canada Memorandum of Intent on Transboundry Air Pollution Aquatic Impact Assessment" prepared and soon to be released jointly by the governments of the United States and Canada. The Wisconsin Department of Natural Resources contributed data and technical review comments to this effort. I have attached a copy of the final report (Appendix B) as further documentation of the susceptibility of Wisconsin's resources to damage from acid rain.

II. In order to determine whether acid deposition has actually impacted Wisconsin's resources the Department of Natural Resources, the Wisconsin Public Service Commission, and the Wisconsin Utilities have planned a series of research projects intended to monitor impacts of acid deposition and to outline potential solutions to the problem.

I have attached as Appendix A a description of these research efforts. I must emphasize that although it appears to be an ambitious and costly commitment on the part of a state which has not documented any "dead lakes" yet we feel it is not adequate to answer the complex questions that have already arisen as a result of two year's work. The dollars and effort outlined in our research plan emphasize Wisconsin's serious concerns about potential damage from acid rain. We need additional funds to carry out an adequate assessment of the acid rain problems in Wisconsin. Recent Federal estimates of the total dollars spent on acid rain research in Wisconsin appear significant on paper but these studies are mostly irrelevant to answering our questions, especially the sources of acidification and the mechanisms of transport. Research funds continue to flow to the already damaged Northeast at the expense of other areas of the nation which still have an opportunity to prevent acidification damage.

III. The State of Wisconsin Natural Resources Board and the Department Secretary advocated that Congress and the Environmental Protection Agency allocate adequate research funds to investigate the sources and potential impacts of acid rain on portions of the upper midwest. They have also urged the EPA and the Congress to investigate appropriate steps to control air pollution from sources contributing to acid rain in Wisconsin. Attached as Appendix C are Natural Resources Board resolutions to this effect and a letter from former Department of Natural Resources Secretary Earl to former Environmental Protection Agency Administrator Costle expressing Wisconsin's position on acid rain.

I would like to point out that the Wisconsin Natural Resources Board endorsed the following six specific policies at its April, 1980 meeting:

1. The Department seek administrative and regulatory action under Section 111(d) of the Clean Air Act. (Section 111(d) authorizes the establishment of standards of performance for any existing source for any air pollutant and procedures for implementation and enforcement of such standards of performance.)
2. A nationwide requirement for coal washing in order to remove substantial quantities of pyritic compounds.
3. Legislative action to amend the Clean Air Act to require nationwide emission limits.
4. Retrofitting of existing power plants to meet nationwide emission limits.
5. Nationwide emission monitoring.
6. Nationwide consistency among EPA regions in requirements and enforcement.

IV. Comments on S. 1709, S. 1706, and S. 1718

General Comments: The Wisconsin Department of Natural Resources is encouraged by the efforts of the three northeastern senators and the tone of the bills introduced this month to begin controlling acid rain. We endorse the concept of an emissions cap and advocate the addition of this concept to the Dodd bill (S. 1718). We feel that the cap should apply only to major sources and should be structured to provide adequate flexibility for sources to utilize existing facilities. We believe emissions of SO_x & NO_x are the primary pollutants of concern and must be curtailed approximately

50% from present levels to accomplish a reduction in acid deposition. We beleive each state in the impact region must be required to contribute to the goal of reduced emissions in an equitable way in order to protect our resources from acid rain.

We agree that states should have more authority and flexibility to determine pollution reduction strategies and welcome innovative options such as state and regional bubbles, marketable emission limits, and SO_x/NO_x trade offs. But we also recognize the growing importance of a strong federal "mediator" to clear up the inevitable interstate disputes which have already arisen. We are, frankly, uneasy about EPA's apparent abandonment of its enforcement posture and wonder how the federal role outlined in these three bills can be meaningfully carried out.

One major shortcoming of all three bills is the lack of emphasis on NO_x as a target pollutant. Although mentioned in all three bills NO_x control does not seem nearly as rigorous as the SO_2 targets. Recent evidence of the rising importance of nitric acid (Galloway 1981) in both eastern and western acid precipitation would seem to dictate a firm stand against relaxation of mobile NO_x limits and institution of vigorous controls of stationary NO_x pollutants. EPA has not demonstrated the will to resist calls for relaxation of transporation pollution limits favoring instead the temporary economic advantages of "deregulation." Control of mobile and stationary NO_x pollutants should be accomplished nationwide not just in the 31-state impact region.

We would like to see the ability provided in the legislation to define impact regions in the future to include those areas west of Wisconsin which are rapidly developing their energy resources and may reasonably be expected to impact Wisconsin (via prevailing westerly winds) in the future. We feel the Dodd bill provides the best approach for reassessment of impact and source area relationships.

We are concerned about the time frames provided to carry out the recommended SIP revisions, emission inventories, innovative options such as bubbles, marketable limits, etc., which are the basis for so many of the provisions of all three bills. Under current state and federal austerity programs the Wisconsin Department of Natural Resources would not be able to revise its SIP in less than 18 months, for example, or provide the kind of detailed emission inventories needed to implement the provisions of the acid rain control bills.

Although not mentioned in the three bills, we believe control of excessive stack height is needed in addition to emission caps to control long range transport of pollutants.

Specific Comments: S. 1718 We believe a bill to limit the impacts of interstate transport of pollutants has long been needed. We support Senator Dodd's comments in the October 7, 1981 Cong. Record dealing with the need for S. 1718. We agree that interstate pollution transport control should not be limited to stationary sources and that the current law lacks the standards and criteria necessary to prove air pollution damage from another state. EPA has not taken an active role in attempting to settle interstate pollution grievances in the past and, in fact, has rejected requests to mediate differences between states obviously impacted by interstate transport.

Having been involved with small scale air modelling projects we agree that criteria other than model results will be needed to determine the impacts of interstate transport of pollutants. The criteria outlined are appropriate but we especially support the ability of the EPA Administrator to establish other needed criteria via regulations if they are promulgated in a timely fashion.

We believe Section 126(a)(2) requiring states to identify existing major stationary sources and the level of pollutants in the level of detail which may be needed to carry out a Section 126 petition will be difficult to produce by July 1, 1982. The current NEDS inventories are inadequate for this purpose and would require considerable state effort (funded by the EPA) to upgrade the quality of information. We feel this should be done by all states as soon as possible but funds are not currently available.

It appears S. 1718 allows states to set excessively high air quality standards at the expense of an adjacent state's ability to allow industrial expansion. Clarification of the intent of the bill on this matter would be useful.

S. 1709 and S. 1706. It is unclear from the text of S. 1709 exactly what actions will be taken by the EPA Administrator if states fail to revise their SIP's to accomplish the goal of air pollution reductions.

Although we concur with the goal of SO_2 and NO_x reductions for the control of acid rain, favor the approach of the Dodd bill (S. 1718) over the Mitchell and Moynahan bills.

It appears that the maximum flexibility afforded by the Dodd bill will insure a more equitable and cost effective solution to the problem of acid deposition.

Because we have had only two days to review these bills and prepare our testimony, we would like to submit a more detailed assessment of the three bills before the close of the comment period.

References

Beamish, R. J. (1976) Acidification of lakes in Canada by acid precipitation and the resulting effects on fishes. Water Air Soil Pollut. 6, 501-514.

Galloway, J. N. and Likens, G. E. (1981) Acid Precipitation: The Importance of Nitric Acid, Atmos. Environ. 15, 1081-1085.

Glass, G. E. and Loucks, O. L., eds. (1980) Impacts of air pollutants on wilderness areas of northeastern Minnesota. EPA Ecological Research Series. EPA-600/3-80-044.

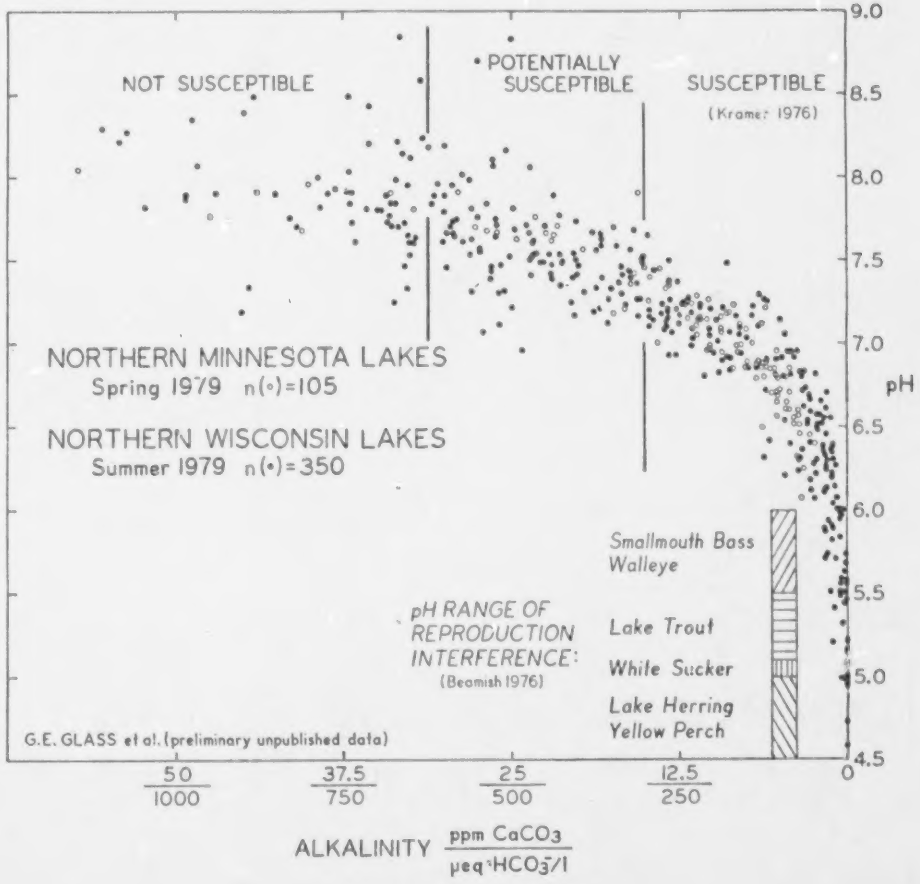
Kramer, J. R. (1976) Geochemical and lithological factors in acid precipitation.: USDA Forest Service Gen. Tech. Rep. NE-23, pp. 611-618.

Likens, G. E., Wright, R, F., Galloway, J. N., and Butler, T. J. (1979) Acid rain, Sci. Am. 241, 43-51.

Schofield, E. J. (1976) Acid precipitation: Effects on fish, Ambio 5:228-230.

Wright, R. F. (1976) Historical changes in the pH of 128 lakes in southern Norway and 130 lakes in southern Sweden over the period 1923-1976. "SNSF-proj." TN 34/77 NISK, As, Norway.

FIGURE 1



G.E. GLASS et al. (preliminary unpublished data)

FIGURE 2

pH OF PRECIPITATION IN NORTHERN WISCONSIN - 1980

Source: Wisconsin DNR

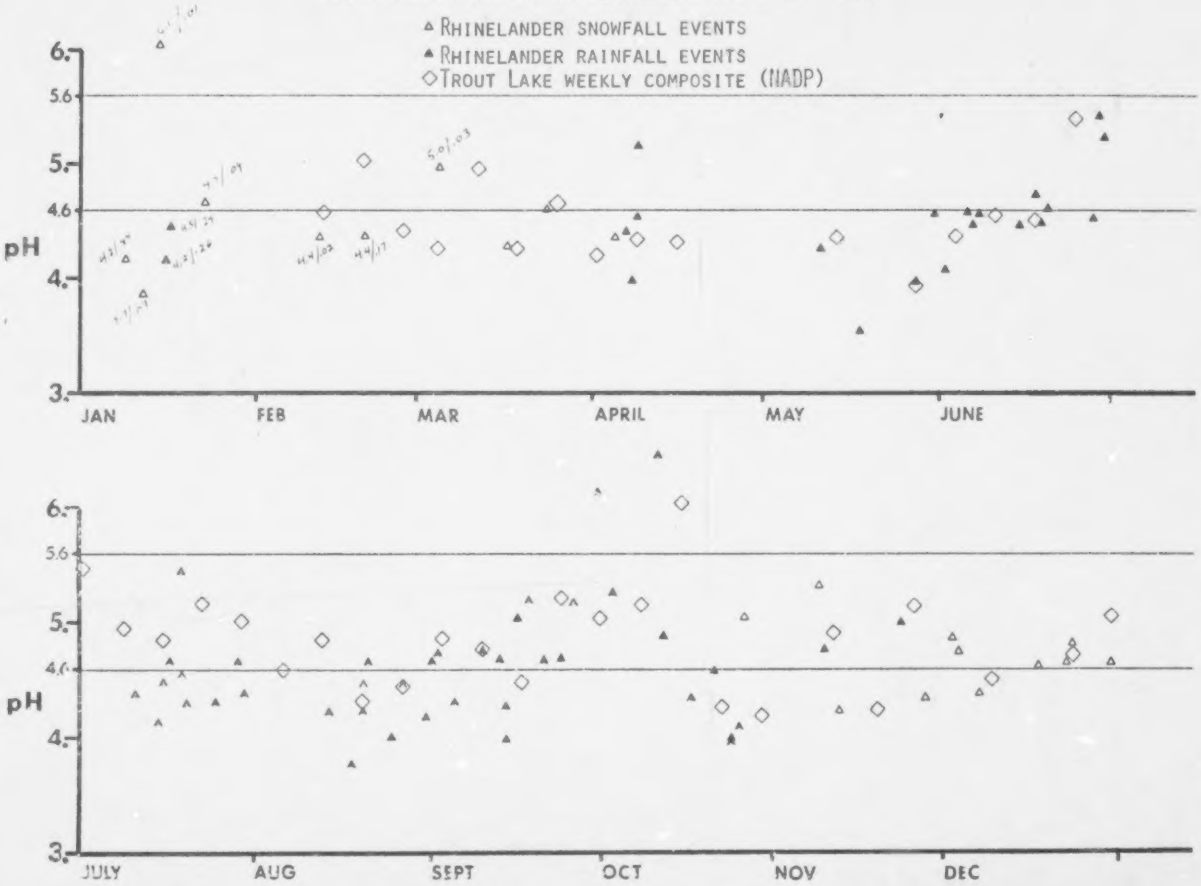
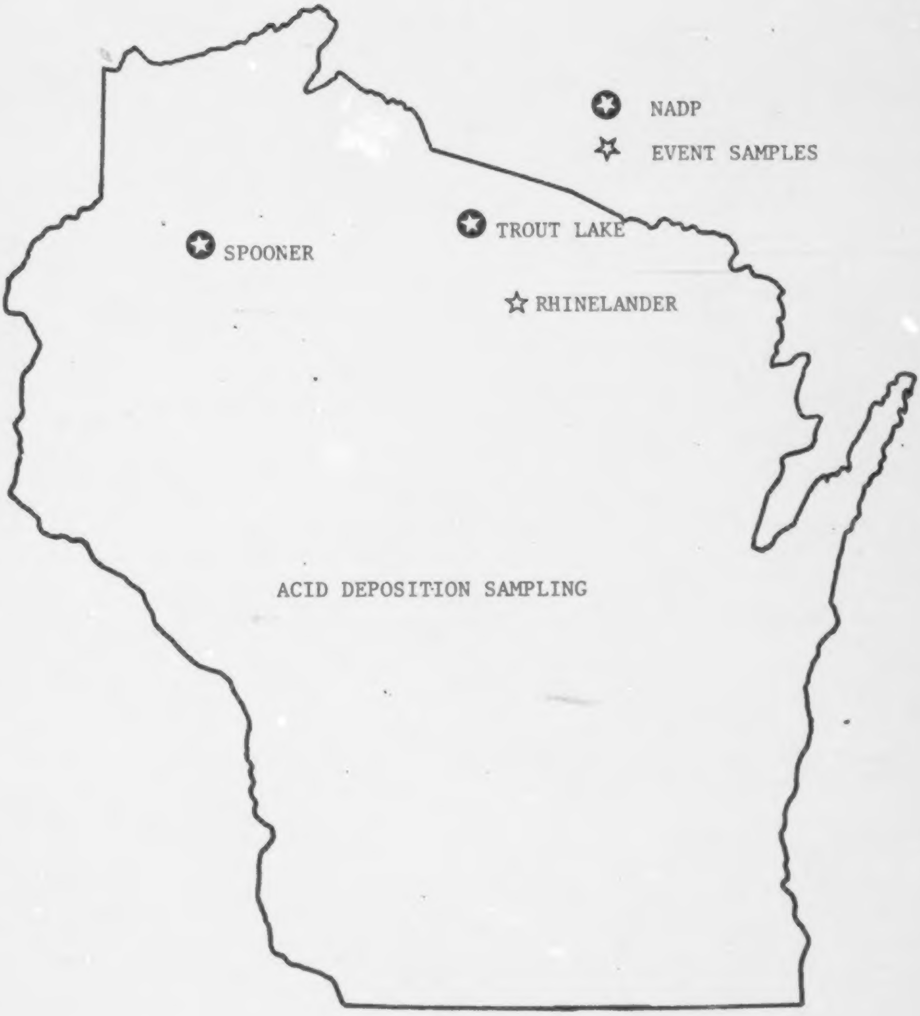


FIGURE 3


NADP
EVENT SAMPLES
SPOONER
TROUT LAKE
RHINELANDER
ACID DEPOSITION SAMPLING

APPENDIX A

CONCEPTUAL PLAN FOR ACID DEPOSITION RESEARCH IN WISCONSIN 1981-1983

Prepared by:

Acid Deposition Joint Technical
Review Committee

March 13, 1981

Wisconsin DNR Representatives:

Thomas Sheffy - Water Quality
Julian Chazin - Air Management
Thomas Wirth - Research
Robert Martini - Water Quality

Wisconsin Utilities Representatives:

Richard Bratcher - Wis. Elec. Power Co.
Merlin Horn - Wis. Power & Light
Thomas Meinz - Wis. Public Service
Anthony Schuster - Northern States Power
Kent Barlow - Madison Gas & Electric
James Musso - Lake Superior Dist. Power
Eric Hennen - Dairyland Power
Robert Raisanen - Upper Peninsula Power

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Thomas B. Sheffy, Chairman
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Richard C. Bratcher, Chairman
Wis. Utilities Acid Deposition
Task Force

Roy Christianson

Roy Christianson, Chairman
Acid Deposition Joint Technical
Review Committee

Preface

The issue popularly referred to as "acid rain" emerged as a significant environmental concern for the people of Wisconsin in early 1980. Industry, the press, the public, state officials and scientists have at times expressed conflicting opinions regarding the potential problem of acid deposition and what should be done about it.

In an effort to assess the potential problem and recommend solutions, an Acid Deposition Task Force was created within the Department of Natural Resources in February, 1980. The Task Force published its findings in a report entitled "A Review of Acid Deposition in Wisconsin; Recommendation for Studying and Solving the Problem" dated June, 1980.

In a parallel effort to examine the problem, Public Service Commission staff developed testimony on long range transport of pollutants and general effects of acid deposition on biota for the PSC 1978 Advance Plan hearing held in March 1980. DNR staff also presented testimony on the Wisconsin situation at the same hearing. Subsequently, the Commission directed major Wisconsin electric utilities to develop a research program consistent with the objectives of a Joint Acid Deposition Technical Review Committee.

In August 1980, the Wisconsin Utilities Association formed its own Acid Deposition Task Force which has reviewed the report from the DNR Task Force and formulated an acid deposition research plan similar to the research strategy outlined in the DNR report.

In September, 1980, representatives from the DNR Task Force,the Utilities Task Force, the Public Service Commission, and the Wisconsin Paper Council formed a Joint Acid Deposition Technical Review Committee. The purpose of the Joint Committee is to integrate the various acid deposition research strategies into one comprehensive research plan for the State of Wisconsin. This report outlines the basic concepts of the integrated research plan. Detailed technical work plans are being drafted by the Joint Committee prior to implementation of the research.

I. What We Presently Know about Acid Deposition in Wisconsin

A. Wisconsin has a large data base on lake water quality dating back to 1925. These data indicate that about 40% of the lakes in the northern half of the state may be susceptible to acidification.

The soils, bedrock, surficial geology, groundwater characteristics, and lake types of northern Wisconsin account for this area's perceived high susceptibility to acid deposition.

B. Based on 1979-80 in-state precipitation monitoring data, Wisconsin is presently receiving acid precipitation, pH approximately 4.5.

Given this regime in Wisconsin--potential susceptibility plus acid deposition--there is concern over whether damage may occur, and if so, in what time frame.

C. The State of Wisconsin generates only about 8% of the total SO_2 and NO_x emissions in EPA Region V. Although part of Wisconsin's acid deposition may be due to local sources, it is unlikely that Wisconsin's emissions alone can account for the total acid deposition occurring in the state. To date no studies have been performed to estimate how much of Wisconsin's acid deposition is due to in-state emissions, how much is due to out-of-state emissions, and how much is due to natural sources.

D. It is possible that the long-range transport of acid rain precursors, due in part to the tall stack trend, from sources as far away as the Ohio Valley, may play a significant role in contributing to Wisconsin's acid deposition. Similarily, air pollutants from Wisconsin may also affect the acidity of precipitation in other states and Canada. A great need exists for research that will accurately describe the long-range transport and deposition process.

E. Research needs in Wisconsin include expanded precipitation monitoring, air trajectory and transport studies, an assessment of emission control strategies, watershed studies, susceptibility studies, and mitigation alternatives.

II. Questions that Need to be Answered

A. Sources of Acid Deposition

1. What is the rate, magnitude, distribution, trend, and pattern of acid deposition in Wisconsin?

Although preliminary data show that acid deposition is occurring in northern Wisconsin, we have no information on acid deposition in other parts of the state. We need to document where and how much acid deposition is occurring, and if the deposition occurs in any seasonal or climatological pattern.

2. Where is the acid deposition coming from? How much of it is due to in-state emissions, how much is due to long-range transport from surrounding states, and how much is due to natural sources?

   Although it is unlikely that Wisconsin's emissions alone can account for the total acid deposition occurring in the state, we need to document the origin of polluted air masses which cause acid precipitation in Wisconsin.

3. What are the emission control alternatives available to each major source in Wisconsin for reducing acidifying substances and their precursors?

   Although the total process of acid deposition is not fully understood, there have been proposals made to reduce emissions of suspected precursors, mainly sulfur dioxide and the nitrogen oxides. It is necessary to determine the feasibility, impact and costs to each source and the public so that any decisions made to control emissions are well founded.

4. What reduction in acid deposition can be expected from the available emission control alternatives?

   At present, limited understanding of source contributions, reaction mechanisms, transport, and other factors make determination of the efficacy of source controls in reducing acid deposition difficult. This determination must be better quantified before cost-effective decisions regarding additional controls can be made.

B. Effects of Acid Deposition

1. Is acid deposition impacting Wisconsin's resources, and if so how rapidly will environmental damage occur if conditions remain unchanged?

   Although preliminary geological, chemical and hydrological data show general susceptibility to acid deposition in northern Wisconsin, we need to document the rate at which our resources will be impacted if acid deposition continues at its present rate.

   We need to conduct research using a holistic watershed approach, that will characterize and predict the impact of acid deposition on terrestrial/aquatic systems. Research of this type involves intensive studies of selected watersheds, documenting the effect and interaction of acid deposition on forests, soils and water resources within the watershed.

2. What is the distribution of susceptible resources in northern Wisconsin?

   General information on the bedrock geology and soil types of northern Wisconsin suggests that much of this area may be susceptible to acid deposition. But susceptibility can be greatly influenced by local geologic anomalies. To adequately define those areas in northern Wisconsin most susceptible to damage from acid deposition, a detailed examination of available data on soils, bedrock and water should be conducted.

3. Has acid deposition impacted low-alkalinity headwater streams in northern Wisconsin?

   Scandinavian and Canadian data indicate that not only lake systems, but also small headwater streams, can be highly susceptible to acid deposition. Historical data on water quality and relative abundance/species composition of fish populations in headwater streams are on file. We need to collect current data on water quality and fish population in these streams and compare them with previous records to determine if these streams are being impacted by acid deposition.

4. What mitigation alternatives are available for restoring acidified lakes or preventing further acidification of aquatic systems?

   We need to compile information on the various techniques that could be used to reverse or neutralize the effects of acid deposition. Which mitigation options are best for Wisconsin's resources if the techniques need to be implemented?

III. Proposed Research Projects

The following research projects are designed to answer the questions posed in section II. The overall research plan is summarized in Table 1. Individual research projects are described on subsequent pages (project numbers and titles correspond to those outlined in Table 1).

Table 1
Summary of the Wisconsin Acid Deposition
Research Plan - 1981-1983

Project No.	Project Name	Objective	Project Manager	Estimated 2 Year Cost	Priority
1.	Deposition Monitoring Network	Quantify rate, magnitude, distribution, trend, and pattern of acid deposition in Wisconsin.	Wis. Utilities Association	$215,000	1
2.	Atmospheric Trajectory Studies	Identify sources of acid deposition precursors which cause acid deposition in Wisconsin.	Event Analysis-Wis. Utilities	$105,000	1
			Quality Assurance - Wis. DNR	$ 25,000	
3.	Intensive Watershed Studies	Determine whether acid deposition is impacting Wisconsin watersheds.	Wis. DNR	$743,000	1
	Project Administrative Cost	DNR has been identified as lead agency for acid deposition research. To administer total research plan, DNR requires a program coordinator for the two-year period.		$ 50,000	
		Total two-year cost for Priority 1 projects and program administration		$1,138,000	
4.	Deposition Data Management	Establish and maintain a quality-assured acid deposition data bank for Wisconsin	Wis. DNR	$ 55,000	2
5.	Atmospheric Transport	Review and rank feasibility of existing models to Wisconsin situation. Identify source regions through the use of long-range transport models.	Wis. DNR	Phase I $ 20,000 Phase II $ 60,000	2
6.	Emission Sources Inven-	Determine all sources which may contribute to acid deposition in Wisconsin.	Wis. DNR	$ 14,500	2

Priority Rating

1 = High, fund and conduct immediately.
2 = Medium, fund and conduct within 2 years

Total 2-year cost for Priority 1 & 2 projects and program administration $1,287,500

HISTORICAL ACID DEPOSITION WORK DONE IN DNR'S NORTH CENTRAL DISTRICT

1. Beginning back in August 1979, DNR's NCD 208 Task Force people held the first conference in Wisconsin on acid deposition.

2. 208 Task Force personnel began sampling of 276 lakes in June 1979 and began related precipitation sampling in September 1979.

3. In November 1979 the first National Atmospheric Deposition Program (NADP) site was established at Trout Lake Station. This is the only site in the nation that was operated and supported by a state agency.

4. Two more NADP-type sites (Starks and Portage County) were established in March 1980.

5. NCD/DNR personnel cooperated on snow core sampling work done by EPA-Duluth in March 1980. A total of 1,300 snow core samples were taken.

6. Spring 1980 sampled another 180 lakes in cooperation with EPA-Duluth.

7. NCD and EPA-Duluth collected fish, zooplankton and macrophytes information on 90 lakes.

8. NCD provided LTE help for U.S. F&WS Weiner study.

9. Fall 1980 resampled 60 lakes, concentrating on multiple observations, including 15 lakes getting 10 samples and 45 lakes with three samples each.

10. Fall 1980 instituted Vandercook and Clara Lakes project with USGS. Set in 23 wells on each lake, sampling station, precipitation sampler, evaporation station and a lake gauge at each lake.

11. Wrote and presented five papers on work done by NCD personnel.

EPA-600/10-81-000
October 1981

APPENDIX B

IMPACT ASSESSMENT OF AIRBORNE ACIDIC DEPOSITION ON THE AQUATIC ENVIRONMENT OF THE UNITED STATES AND CANADA

Edited by

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This report has been prepared by the bilateral technical committee on aquatic impacts established by the Memorandum of Intent on Transboundary Air Pollution between the United States and Canada. The conclusions and recommendations do not necessarily reflect the views and official policies of the U.S. Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

ACKNOWLEDGEMENTS

The Co-chairmen gratefully acknowledge the many contributions made by members of the subgroup during the 10-month study. The contributors from the United States included: Orie L. Loucks, The Institute of Ecology; R. Kent Schreiber, U.S. Fish and Wildlife Service; Carl Schofield, Dept. of Natural Resources, Cornell University; and Anders Andren, Dept. of Water Chemistry, University of Wisconsin.

The contributors from Canada included: William Ayre, New Brunswick Department of Environment; Gail Beggs, Ontario Ministry of Natural Resources; James Cooley, Canada Department of Fisheries and Oceans; Floyd Elder, National Water Research Institut, Canada Department of the Environment; Kathy Fischer, Canadian Wildlife Service; Lucy Metras, Environmental Protection Service; Henri St. Martin, Chef de Service, Qualité des Eaux Environment Québec; and R. Sandhu, Alberta Department of Environment.

In addition, many other individuals at the Ontario Ministry of Environment, Toronto; the National Water Research Institute, Burlington; the Environmental Research Laboratory, EPA, Duluth; and The Institute of Ecology, Indianapolis, have provided invaluable services throughout the development of the study and the preparation of this report.

ABSTRACT

This project provided for United States participitation in the Aquatic Impacts Subgroup of Work Group I (Impacts Assessment) established in 1980 under the U.S./Canada Memorandum of Intent regarding long-distance pollutant transport and its effects. Dr. Glass serves as Chairman of the U.S. subgroup participants, Dr. Brydges as Chairman of the Canadian participants, and Dr. Loucks serves as Project Manager of the Cooperative Agreement between EPA and TIE which has supported the U.S. activity.

The report represents the cumulative product of the Phase I study (November, 1980 to January, 1981), external review of the draft Phase II report (May, 1981), and the extensive revisions carried out during July and August, 1981. The results are being incorporated, with some revision, in an overall report on terrestrial, material, and health effects for the complete Work Group I report under the U.S./Canada Memorandum of Intent.

The findings of the study deal primarily with (1) the processes by which acidic inputs to watersheds can produce alterations of water quality and biological effects; (2) a survey of the geographic extent of water quality changes; (3) an evaluation of data on mechanisms and extent of biological effects believed to have resulted from acidic inputs; (4) an assessment of the relative significance of sulfate vs. nitrate inputs in acidification processes; (5) a review of existing models which allow estimation of acid loadings apparently within the buffering "tolerances" of watersheds in the U.S. and Canada; and (6) research needs to address uncertainties in the information base.

GLOSSARY OF CHEMICAL NAMES AND SYMBOLS*

Symbol	Name	Symbol	Name
Ag	Silver	Mg^{++}	Magnesium ion
Al	Aluminum	Mn	Manganese
Al^{3+}	Aluminum ion	Mn^{++}	Manganese ion
$Al(OH)_3$	Aluminum trihydroxide	Mo	Molybdenum
As	Arsenic	N	Nitrogen
Au	Gold	NH_3	Ammunia
B	Boron	NH_4^+	Ammonium ion
Be	Beryllium	NO	Nitrogen oxide
Br	Bromine	NO_2	Nitrogen dioxide
C	Carbon	NO_3^-	Nitrate ion
CO	Carbon monoxide	N_2O	Nitrous oxide
CO^{++}	Carbon monoxide ion	Na	Sodium
Ca	Calcium	Na^+	Sodium ion
Ca^{++}	Calcium ion	Ni	Nickel
$CaCO_3$	Calcium carbonate	O_3	Ozone
Cd	Cadmium	OH^-	Hydroxide ion
Cl	Chlorine	P	Phosphorus
Co	Cobalt	Pb	Lead
Cr	Chromium	Ra	Radium
Cu	Copper	Rb	Rubidium
F	Fluorine	SO_2	Sulfur dioxide
Fe	Iron	SO_4	Sulfate
Fe^{3+}	Iron ion	$SO_4^=$	Sulfate ion
Ga	Gallium	Sb	Antimony
Ge	Germanium	Se	Selenium
H	Hydrogen	Si	Silicon
H^+	Hydrogen ion	Sn	Tin
HCl	Hydrogen chloride (Hydrochloric acid)	Sr	Strontium
HCO_3^-	Hydrogen carbonate ion (Bicarbonate ion)	Ta	Tantalum
HNO_3	Nitric Acid	Te	Tellurium
H_2CO_3	Carbonic acid	Th	Thorium
H_2S	Hydrogen sulfide	Ti	Titanium
H_2SO_4	Sulfuric Acid	U	Uranium
Hg	Mercury	V	Vanadium
Hg^{++}	Mercury ion	V^{++}	Vanadium ion
K	Potassium	W	Tungsten
K^+	Potassium ion	Zn	Zinc
Li	Lithium	Zn^{++}	Zinc ion
Mg	Magnesium	Zr	Zirconium

* Elements and compounds are cited usually without valence strengths; valences have been retained when required for discussion of ionic balances or in quotations from another author.

PROJECT SUMMARY

Impact Assessment of Airborne Acidic Deposition on The Aquatic Environment of the United States and Canada

Gary E. Glass, Thomas G. Brydges and Orie L. Loucks

This project provided for United States participitation in the Aquatic Impacts Subgroup of Work Group I (Impacts Assessment) established in 1980 under the U.S./Canada Memorandum of Intent regarding long-distance pollutant transport and its effects. Dr. Glass serves as Chairman of the U.S. subgroup participants, Dr. Brydges as Chairman of the Canadian participants, and Dr. Loucks serves as Project Manager of the Cooperative Agreement between EPA and TIE which has supported the U.S. activity.

The report represents the cumulative product of the Phase I study (November, 1980 to January, 1981), external review of the draft Phase II report (May, 1981), and the extensive revisions carried out during July and August, 1981. The results are being incorporated, with some revision, in an overall report on terrestrial, material, and health effects for the complete Work Group I report under the U.S./Canada Memorandum of Intent.

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Introduction and Objectives

The objective has been to develop and report a summary of United States and Canadian scientific understanding as to the nature and apparent magnitude of the problem of acidic deposition effects in aquatic systems. The work should be viewed as part of the series of reports being prepared under the MOI. The draft report was distributed for peer review in May, 1981, and has been revised accordingly; nevertheless, the findings remain subject to modification as further advances in scientific understanding become available.

Principal Results

Regional Patterns of Acidic Inputs: Wet and dry deposition of acidic and other constituents in long-distance pollutant transport are currently being observed in most of eastern North America. Within this half-continent are large areas in which the surface soil material and bedrock types have little buffering capacity for the acidic inputs and are identified as "potentially sensitive".

The four most susceptible regions in the United States, based on the acid neutralizing constituents of bedrock and soils, are the Northeast, the Appalachian Mountains, the Minnesota-Wisconsin-Michigan highlands, and the western mountain areas of Colorado, Washington and California. In Canada, sensitive regions include parts of the Atlantic Provinces and the Precambrian shield areas of Ontario and Quebec.

The relative importance of each aspect of deposition, i.e., dry vs. wet, is still being evaluated, but results so far indicate wet and dry deposition of sulfur compounds are of about equal importance on an annual basis in much of northern Europe and North America. Dry deposition is apparently of lesser importance in remote areas.

Regional Patterns of Water Quality Alteration: The potential impacts from the deposition of acidifying substances (sulfur and nitrogen oxides, ammonium and acids, etc.) on water quality, and on the aquatic ecosystem, appear to be more fully quantified and understood than are impacts for terrestrial ecosystems. A number of examples have been observed where dramatic changes in water quality are believed to be attributable to atmospheric acidic inputs. An eastern North American cross-section of data on excess sulfate in surface waters, considered in relation to the measured wet deposition waters, considered in relation to the measured wet deposition of sulfate, provides strong support for the view that it is the atmospheric deposition which accounts for elevated sulfate levels in surface waters.

Because of the low Ca and Mg concentrations in these waters, high SO_4 concentrations lead to greatly depressed alkalinity. Of the 1,527 lakes recently surveyed in Ontario, 18% were classified as extremely sensitive, i.e., having an alkalinity of 0 to 40 microequivalents per litre (μeq/ℓ), and an additional 43% were considered moderately sensitive. Alkalinity data for the surface waters of sensitive regions in the eastern U.S. (areas with low soil cation exchange capacity, non-buffering bedrock types and low sulfate adsorption) show 38 to 81% of lakes and streams have moderately sensitive to acidified alkalinities (from less than 0 to 200 μeq/ℓ). Thirteen to 48% of midwestern lakes and streams are in these categories. Many of the affected lakes are not technically acidified (in the sense of depressed pH), but the long-term biological consequences of the altered water chemistry are not fully known at this time. Although naturally acid lakes do occur, the number of seriously acidified non-bog lakes appears to be a recent response to continued acidic deposition.

A downward trend in pH over time is evident from several studies. High elevation lakes in the Adirondacks have shown a marked pH decline over a 40-year period. Mountain streams in Virginia and North Carolina have shown changes over the past two decades. These are among the most sensitive lake and stream districts in the eastern United States and a recent inventory indicates that at least 180 former brook trout ponds in the Adirondacks no longer support trout, apparently because of acidification. A 17-year trend toward acidification of headwater streams has been observed in New Jersey.

Researchers differ and the evidence seems to be conflicting as to whether the geochemical alteration of watersheds due to acidic inputs should be viewed as irreversible, and, if so, on what scale. Irreversibility can be viewed as a failure to recover over geological time; but, for natural resource systems, an incomplete recovery to a prestressed or undamaged state over a few decades, for all practical purposes, may be regarded as irreversible.

Alteration of Aquatic Biota: Many changes in aquatic life have been linked to acidification. In some instances a causal relationship with depressed pH has been established, but in most cases, the observed changes in biota have simply been correlated with observed changes in pH. For most biological communities, acidification has been accompanied by decreases in species diversity and changes in species dominance. Acidification results in changes in the makeup, size and metabolism of plankton communities. These alterations hold important implications for other organisms higher in the food chain.

Fish populations appear to have been lost from some lakes in Ontario by the time of the first surveys, 1965-66; others had populations that were endangered, and still others were apparently in a healthy condition at that time. The impact of acidification on salmon angling success in Nova Scotia is reflected in a study of 22 rivers with complete angling records and no structural alterations: of two groups of rivers, ten are presently at pH less than 5.0, and 12 are at pH greater than 5.0. Of the 10 rivers with pH's less than 5.0, 9 show significant declines, and 1 shows no significant trend; of those above pH 5.0, 10 show no significant trend.

Many species of frogs, toads and salamanders breed in temporary pools susceptible to pH depression due to the rapid flushing of accumulated acid during spring snowmelt. Field surveys in North America and Europe have documented the sensitivity of amphibians to depressed pH and the decreases in their numbers. The danger that they may become locally extinct, and their significance in the food chain, hold important implications for other wildlife.

Acidic deposition effects on unique ecosystems and rare and endangered species are likely to be expressed through local extinctions and decreased genetic diversity. Aesthetic values of affected ecosystems may be affected by changes in dominant species composition. Many of these unique systems are presently state, provincial or national parks and forests in both the United States and Canada, and are protected by federal and local law.

The Significance of SO_4 vs. NO_3 for Effects on Aquatic Systems: Soil and plant interactions with nitrate ions allow the nitric acid input to be assimilated (often > 80%) by the terrestrial portion of the watershed. Conversely, in many poorly buffered acid bedrock areas, biological interactions with the sulfate ion are small in comparison to the mass balance of sulfur. Thus, SO_4 can be viewed as a relatively conservative anion in many watersheds and, therefore, likely to show a direct relationship between SO_4 concentrations observed in precipitation and those observed in lakes and streams. Additional aspects of the issue include variations in the relative magnitude and seasonal distribution of SO_4 and NO_3 in the rain and snow; the relative importance of the biological interactions of both anions in watersheds, as they are affected by biological activity at different seasons; and the potential for alkalinity production in aquatic systems through the addition of NO_3 when N is a partially limiting nutrient for plant growth.

On balance, the evidence available leads to a conclusion that recent increases in the acidity of surface water systems are primarily the result of increased sulfuric acid reaching these waters. Although nitric acid has been observed to contribute some acidity in surface waters during snowmelt in certain locations, there is little theoretical or empirical evidence for anticipating appreciable reduction in lake or stream acidification from a reduction of nitric acid inputs. Conversely, a reduction in sulfate loading will, in time, reduce the observed sulfate concentrations and associated acidification of surface waters.

Target Sulfate Loadings and Dose/Response Relationships: A number of different approaches have been examined to assist in deriving relationships between measures of acid loading and system response. These models are all under active development, but they have advanced to the point where preliminary applications are possible. However, it is important to stress that full validation remains to be achieved.

One model, based on Scandinavian data, indicates that annual sulfate loadings of less than 15 to 17 kg/ha would be unlikely to degrade "moderately sensitive" lakes. The most sensitive lakes and streams are likely to be on the borderline of potential effects at a long-term annual sulfate loading rate greater than 9 to 12 kg/ha.

A second model shows that precipitation pH of 4.5, and lakewater SO_4 concentration of 60 μeq/ℓ, are the maximum tolerable for lake waters with 50 μeq Ca/ℓ or more. This in-lake concentration of sulfate converts to a precipitation sulfate concentration of about 40 μeq/ℓ. Highly sensitive lakes and streams seem likely to be protected at precipitation sulfate concentrations of 21 μeq/ℓ. A third model, based on data from eastern Canada, corroborates these findings. A fourth model, using North American stream data, combines the physiological sensitivity of early life stages of fish, the acute effects of H and Al, and data on pH during flushing events (snowmelt or heavy rain). This model indicates a sulfate loading of 5 to 7 kg ha^{-1} yr^{-1} produces a critical surface water response (ΔpH in the range of 0.7 to 1.0) for streams in sensitive areas: a loading threshold of 7 kg SO_4 ha^{-1} yr^{-1} converts to about 21 μeq SO_4/ℓ (assuming 70 cm/yr precipitation). Although the indicated dose/response relationships among these models are relatively consistent, the estimates must be viewed as preliminary.

Regardless of the model used to determine threshold loading values, certain variables lie outside the purview of effects modeling. One is the number of lakes placed at risk by a given "loading tolerance" which society may choose not to protect. Lake sensitivity is a function of geochemical processes in highly variable lakes and watersheds; abatement to a level that protects the single most sensitive stream or lake in the U.S. or Canada is probably not feasible. When aquatic systems are inventoried according to defined sensitivity measures, a cutoff point may then be determined for various loading tolerances. These results indicate that reductions in sulfate deposition of from 50% to 75% are required to protect the most sensitive aquatic systems in the most heavily loaded areas of North America.

Research Needs

Although some aspects of lake and stream acidification processes are well known, the results reviewed here identify numerous gaps in the information on regional sensitivity, effects, and predictive capabilities as to long-term responses. There is an immediate need in both the United States and Canada for improved knowledge as to the nature of geochemical alterations affecting water quality, the associated biological effects, and on modeling the dose/response relationship. Critical research topics include:

- defining, in specific terms, the fate and effect on surface waters of hydrogen, ammonium, sulfate and nitrate ions originating as atmospheric input;
- defining the rate of acidification of surface waters, develop predictive models to quantify watershed capacity to neutralize acid over the long term, and to anticipate recovery following abatement;
- defining the amounts and species of metals leached from watersheds and their biological consequences;
- establishing the extent and characteristics of groundwater modification over time and across geographical gradients in acid loadings;
- determining the quantitative relationship between acidic deposition and short-period pH depression for a broad spectrum of aquatic environments;
- improving the general understanding of the fish toxicity phenomenon and defining the biological effects and tolerances for periodic pH depression and aluminum elevation in streams and lakes;
- measuring existing mercury concentrations and time trends throughout the wildlife food chain as a function of lake and stream pH values;
- beginning long-term water quality measurements in a carefully selected range of aquatic environments as soon as possible.

Because acidification is found most frequently in remote, rocky areas unaffected by local discharges, very few areas exist with long-term baseline information. Studies of calibrated watersheds should be intensified with the general objective of improving the estimates of rates of changes in water quality and biological effects relative to acid loadings (i.e., dose/response relationships). Analyses should be undertaken of all available baseline studies (particularly in the U.S.) including regional monitoring of surface water quality, plankton, fauna, soil, and vegetation records. Unless a water quality and biological effects monitoring program can be in place, providing a documented time-series of system properties, there will be little capability in the future to quantify results of either reduction or increase in acidic deposition.

IMPACT ASSESSMENT OF AIRBORNE ACIDIC DEPOSITION ON THE AQUATIC ENVIRONMENT OF THE UNITED STATES AND CANADA

INTRODUCTION

World attention was drawn to the problem of transboundary air pollutants and their deposition on surface waters in 1972, when Sweden and Norway reported the so-called "acid rain" phenomenon. From these Scandinavian studies, scientists in many other nations became increasingly aware that, because atmospheric dilution does not eliminate waste, there may be effects on "receiving" aquatic ecosystems caused by the transport and deposition of pollutants. Since 1972, the acidic deposition phenomenon has become recognized in North America, as detailed in many articles by both Canadian and United States scientists.

This Aquatic Impacts assessment is structured to deal with three major questions about aquatic impacts of long-range pollutant transport and deposition in North America:

1. What are the nature and extent of the chemical alteration of the hydrologic cycle due to pollutant deposition?
2. What are the nature and extent of biotic alteration in aquatic ecosystems as a result of acid-induced chemical alteration?
3. What are the geographical distribution and acid loading tolerance, or threshold, for watersheds of varying sensitivity?

This report uses several approaches to these questions. First, emphasis is placed on identifying and substantiating all effects possibly related to transboundary air pollution. This evaluation has required some consideration of the complexity of hydrologic systems as well as of the complexity and the extent of aquatic resources which are at risk. Included are detailed documentations of impacted aquatic environments, both chemical and biotic components, and definition of the time trends for observed effects on these components.

Secondly, this report considers the significance of the episodic nature of atmospheric pollutant loading, and pollutant flushing processes, such as snowmelt, as well as the seasonal character of the receiving environments, such as periods of spawning. Thus, these sections relate pollutant loading levels to the observed extremes in chemical and biological effects.

Finally, this report focuses on the aquatic areas and populations which are sensitive to acidic deposition, believed to result from transboundary air pollution. It is, therefore, necessary to define an acid-loading tolerance and to list aquatic resources at risk from higher loading levels and to discuss recovery possibilities for aquatic systems showing apparent damage.

PROBLEM COMPLEXITY AND APPROACHES TO MEASURING AQUATIC IMPACTS

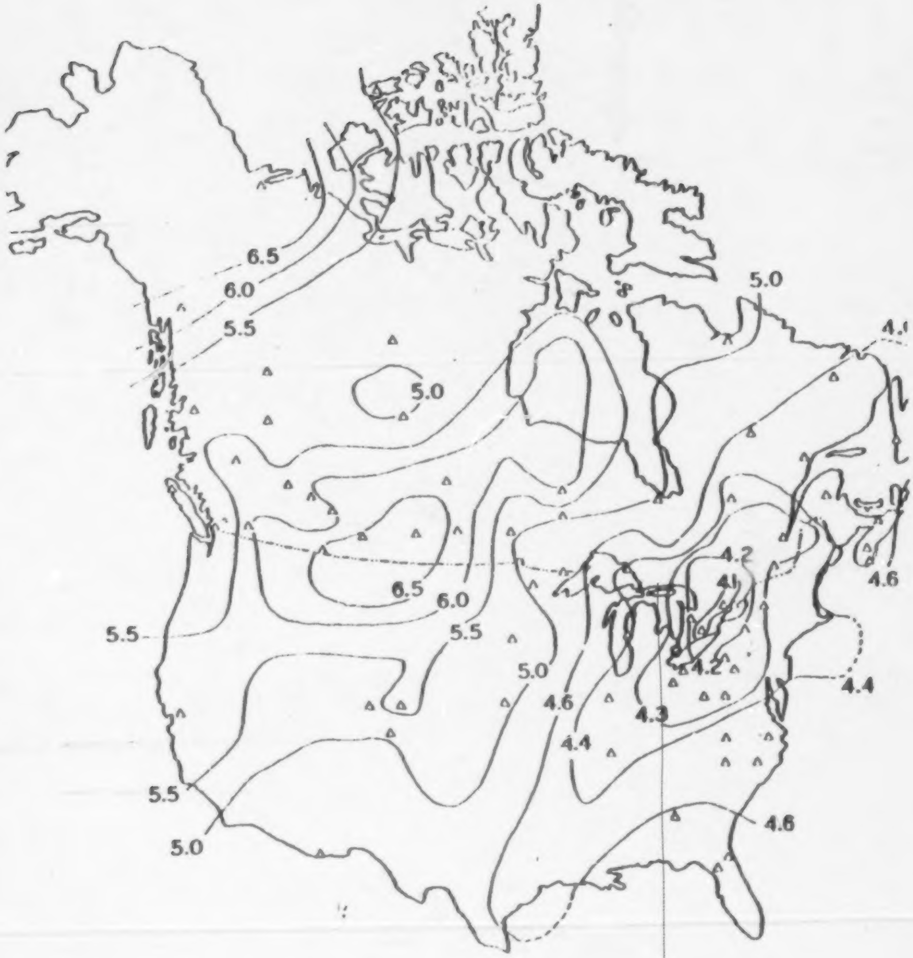
The Extent of Resources at Risk and Potential for Large-Scale Effects

Acidic deposition is currently being observed in most of eastern North America (Figure 1). Within this half-continent are large areas in which the surficial soil material and bedrock types have little ability to neutralize acids, and which are identified as "potentially sensitive". There are several hundred thousand lakes in these areas at various degrees of risk from acidification. Water covers about 8% of the surface area and plays a major role in the food chain of fish and wildlife in the region. The effects on watersheds and aquatic resources are most strongly expressed in the areas where elevated inputs of acid combine with low natural buffering of soils and water to reduce the pH of surface water, leading to the extinction of fish populations. An important question, to be explored in future studies, is whether the responses observed to date represent a time trend, thus suggesting that many more lakes will be affected in the future, or a steady-state of inputs and weathering, thus suggesting little increase in the extent of damage, even if current acid loadings continue.

The recently recorded effects on resources in sensitive areas are cause for concern in Canada, New England, the midwest states, Florida, and mountainous regions of the west. Over most of this area, acidic deposition, sulfate particulates, and oxidants occur together. In addition, there are local exposures occurring to sulfur dioxide, nitrogen oxides and fluorides, with biological uptake and subsequent cycling of these compounds. The acidic substances appear, directly or indirectly, to cause most of the effects observed on aquatic life forms.

The potential is high for widespread environmental degradation from acidic and other pollutant deposition, because hydrogen ion concentration (acid, H) in the aquatic environment is a critical factor controlling the rate of most chemical reactions. Processes such as solubilization, corrosion, and mobilization of minerals and metals, are accelerated by increasing the acid concentrations in soils and water. Soil weathering and nutrient balances are altered by changes in the acidity of soilwater. Household water supplies from shallow wells or acidic surface waters, in turn, can be modified by the further mobilization of metals from lead and copper pipes. Metal culverts at stream crossings are especially susceptible to corrosion from mild acidity (see Materials Subgroup report in this series).

Despite the universal nature of these response processes, the potential susceptibility of watersheds to environmental damage from acidic deposition is quite different from one region to another, due to differences in climate, soils, and geology. The four most susceptible regions in the United States, based on bedrock geology, are the Northeast, the Appalachian Mountains, the Minnesota-Wisconsin-Michigan highlands, and the western mountain areas of Colorado, Oregon, Washington, Idaho, and California (Figure 2). In Canada, sensitive regions include parts of the Atlantic Provinces and the Precambrian shield areas of Ontario and Quebec. Other areas may be considered sensitive based on soil characteristics or other variables.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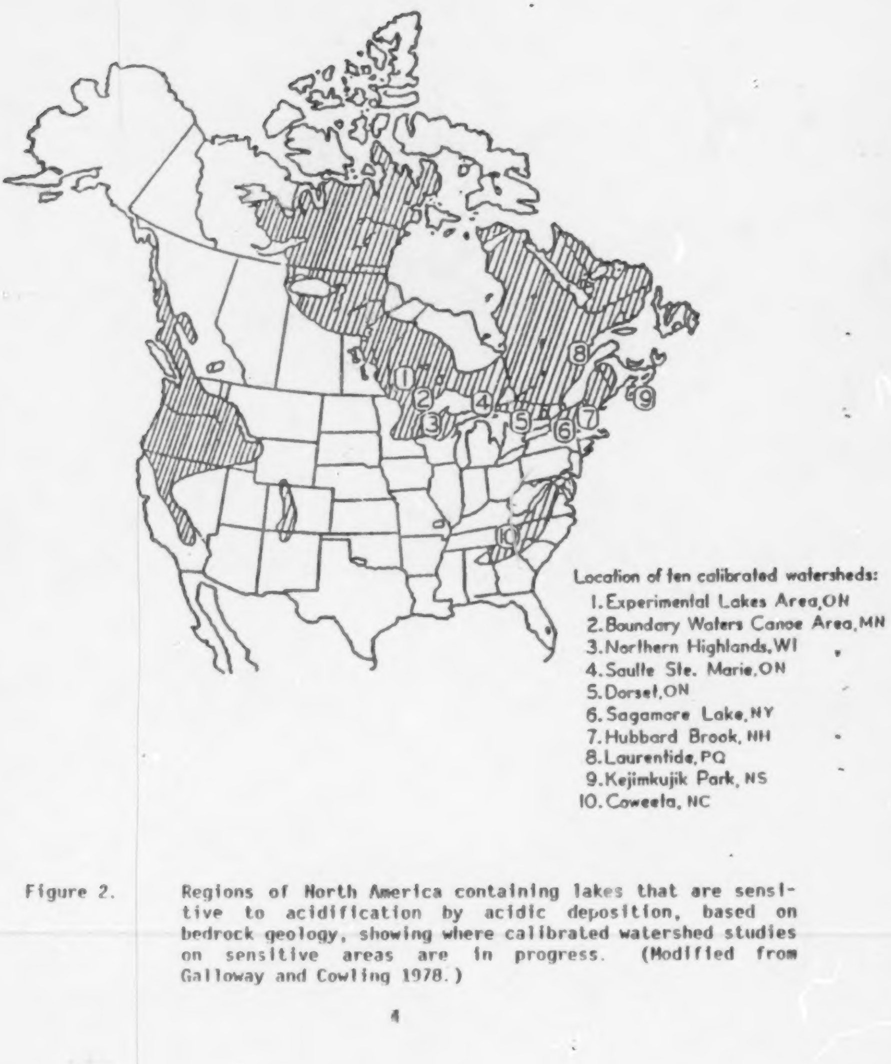
igure 1. pH of precipitation in North America, volume weighted averages for the period April 1979 to March 1980. Data reporting sites (Δ) are from the NADP and CANSAP precipitation monitoring networks (Glass and Brydges 1981).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Location of ten calibrated watersheds:
1. Experimental Lakes Area, ON
2. Boundary Waters Canoe Area, MN
3. Northern Highlands, WI
4. Saulte Ste. Marie, ON
5. Dorset, ON
6. Sagamore Lake, NY
7. Hubbard Brook, NH
8. Laurentide, PQ
9. Kejimkujik Park, NS
10. Coweeta, NC

Figure 2. Regions of North America containing lakes that are sensitive to acidification by acidic deposition, based on bedrock geology, showing where calibrated watershed studies on sensitive areas are in progress. (Modified from Galloway and Cowling 1978.)

What is known of the complexity and geographic range of acidic deposition-ecosystem interactions and long-distance transport of air pollutants may pose a significant dilemma for federal, state, and provincial regulatory agencies. Aquatic life is apparently being damaged by regional air emissions, but air quality standards were not designed to protect water quality. Nevertheless, important resources over a large part of the continent appear to be at risk, and new multinational control approaches may be required.

Methods of Measuring Effects

Lakes, rivers, and watersheds act as "collectors" of atmospheric pollution, so one research approach has been to study lakes and watersheds as large-scale "calibrated" collectors, since the surface environment experiences a total loading, an integration of all deposition processes. This approach has led to establishing "calibrated watersheds" as monitoring sites which are combinations of streams, lakes, and plant communities under intensive measurement. In these watersheds, hydrologic weirs are set up in streams entering and leaving small study lakes or settling pools. The flows of water and dissolved substances are measured upon entering and leaving the lake, and these data are combined with measures of atmospheric inputs and water loss by evaporation to calculate "substance budgets". The difference between the inputs measured by the budgets with inputs measured from wet deposition monitoring can provide a preliminary estimate of dry and gaseous deposition.

Detailed sampling of biota within such a watershed, together with chemical data, allows an assessment of the chemical and biological effects that air pollution can have on the system. Calibrated watersheds have been established at a number of locations such as Kenora, Sault Ste. Marie and Dorset in Ontario; Laurentide Park, Quebec; Kejimkujik Park, Nova Scotia; Hubbard Brook, New Hampshire; Coweeta, North Carolina; and Sagamore Lake, New York (Figure 2).

The Hydrologic Cycle

Although the hydrologic cycle seems to be well-known, questions do emerge as to the potential for high evaporation/precipitation ratios to concentrate sulfate and the availability of water for many of the acid-forming reactions as well as for the wet deposition and soil flux processes. For example, in low-humidity regions, or during drought periods, long-distance gaseous transport of SO_2 may provide a greater fraction of the deposition than in wet regions. Similarly, conditions of low rainfall and high evaporation, or seasonal droughts, will alter the soil solution flux and associated reactions. In regions where annual precipitation is less than potential annual evaporation, movement of dissolved ions is upward (calcification). This movement of bases would tend to neutralize acidic deposition falling onto soil surfaces. Indeed, in regions where potential evapotranspiration approaches total rainfall, flushing of H or SO_4 becomes limited to short-season processes or those that occur only every few years.

Because of the evidence that in poorly buffered, northern soils, the sulfate ion is a relatively conservative substance (Harvey et al. 1981), high rates of evaporation can leave the precipitation sulfate concentrated in the soil solution (and lake water) by a factor controlled by evaporative losses. The equations for lake sulfate concentration developed by Henriksen (1980, see later sections) show this factor plus the dry deposition to be 1.9 for central Norway. Regions of proportionately higher evaporative losses are expected to have higher observed sulfate concentrations in lake water than are predicted by the Henriksen equations for a given atmospheric loading rate (Glass and Brydges 1981). These processes vary with precipitation and temperature patterns between regions and, in areas of strong topography, from one watershed to the next.

Thus, local processes governing the hydrologic balance need to be considered as a part of the surface water acidification process. Knowledge of the periodicity of atmospheric cycles, and the geographic patterns of these transport processes and precipitation are essential to understanding what happens over long periods to sensitive aquatic systems, as well as when and where it will happen.

ATMOSPHERIC INPUT, TRANSPORT, AND DEPOSITION OF POLLUTANTS

Emissions of Pollutants to the Atmosphere

Extensive research attributes most of the acidity in rainfall over eastern North America, and elsewhere, to the presence of sulfuric and nitric acids. These acids are formed by a complex series of chemical and physical processes during, and subsequent to, the burning of fossil fuels, ore smelting, and petroleum refining. Vehicular transportation, construction, agriculture, municipal incineration, use of home wood-burning stoves, and natural processes also contribute to the atmospheric burden. Other substances are also emitted to the atmosphere during these processes. Prevailing weather conditions in eastern North America foster the large-scale movement of pollutants within and between Canada and the United States, so that the movements of pollutants are regional issues.

A recent report presents estimates of 1975 sulfur dioxide and nitrogen oxide emissions for the two countries, along with maps showing the geographical distribution of emissions (Altshuller and McBean 1980). The report is concerned with eastern North America, which embraces the industrial heartlands of both countries, wherein are most of the aquatic ecosystems which have been determined to be most vulnerable to acidic deposition. Annual sulfur dioxide emissions were estimated at 5 billion kg (kilograms) in Canada and 26 billion kg in the United States. Annual nitrogen oxide emissions were estimated at 1.9 billion kg in Canada and 22 billion kg in the United States. Substantial increases in these emissions are expected if consumption of fossil fuels continues to increase. Estimated emission rates for other constituents from the burning of coal are presented in Table 1. Estimates by Goldberg and Bertine (1971) and Klein et al. (1975) indicate that the amount of many trace constituents emitted to the atmosphere via the burning of coal in the U.S. approximates the quantity transported via rivers from continents to oceans. A U.S. National Academy of Sciences report (1978) further estimated that from 25 to 30 percent of the present day atmospheric mercury burden is due to man-made emissions.

TABLE 1. AIR EMISSIONS FROM A TYPICAL 1000 mw COAL-FIRED STEAM PLANT[1].

Constituent	Mean concentration in coal[2]		Annual air emission (kg/yr)
Major			
Ash	11.4	(%)	2.5 x 10^6
Total carbon	70.3	(%)	10^{10} (as CO_2); 10^7 (as CO)
Total sulfur	3.3	(%)	65 x 10^6
Water	9.	(%)	450 x 10^6
Total nitrogen	1.3	(%)	10 x 10^6 (as NO_x)
Al	1.3	(%)	0.24 x 10^6
Ca	0.77	(%)	0.14 x 10^6
Cl	0.14	(%)	7 x 10^6 (mostly vapor)
Fe	0.9	(%)	0.31 x 10^6
K	0.16	(%)	0.062 x 10^6
Mg	0.05	(%)	0.014 x 10^6
Na	0.05	(%)	0.02 x 10^6
Si	2.49	(%)	0.54 x 10^6
Ti	0.07	(%)	0.034 x 10^6
Minor			
Organic C	-		5000.
Fluoranthane	-		35.
Benzo(ghi)perylene	-		14.
Benzo(a)pyrene	-		13.
Benzo(e)pyrene	-		7.
Pyrene	-		13.
Perylene	-		6.
Phenanthrene	-		3.
Coronene	-		0.6
Ag	0.1	(ppm)	31.
Au	0.001	(ppm)	0.3
As	14.	(ppm)	3,500.
B	102.	(ppm)	3,100.
Be	1.6	(ppm)	80.
Br	15.4	(ppm)	70,000. (mostly vapor)
Cd	2.5	(ppm)	680.
Co	9.6	(ppm)	540.
Cr	13.8	(ppm)	1,700.
Cu	15.2	(ppm)	915.
F	61.	(ppm)	15,000. (40% as vapor)
Ga	3.1	(ppm)	172.
Ge	6.6	(ppm)	1,600.
Hg	0.2	(ppm)	1,000. (mostly vapor)
Li	9.	(ppm)	365.
Mn	49.4	(ppm)	1,500.
Mo	7.5	(ppm)	940.
Ni	21.1	(ppm)	1,300.
P	71.1	(ppm)	2,700.
Pb	34.9	(ppm)	11,000.
Ra			0.1 (Ci)
Rb	40	(ppm)	1,200.
Sb	1.3	(ppm)	360.
Se	2.1	(ppm)	335. (20% vapor)
Sn	4.8	(ppm)	1,200.
Sr	34	(ppm)	1,100.
Ta	0.16	(ppm)	6.5
Te	50	(ppm)	2,500.
Th	3.1	(ppm)	96.
Tl	680	(ppm)	33,000
U	5	(ppm)	260
V	32.7	(ppm)	3,400.
W	1	(ppm)	30.
Zn	272	(ppm)	37,000.
Zr	72.5	(ppm)	2,200.

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[1] Plant has electrostatic precipitator efficiency of 99.5%, no scrubbers, and consumes 5 x 10^6 tons of coal per year.

[2] Western, midwest and eastern coal mean of 101 samples.

FROM: Bauer *et al*. 1982a, 1982b; EPRI 1980, Klein *et al*. 1975; NAS 1977; ORNL 1977.

Much study is presently being devoted to the characterization of emissions from both natural and anthropogenic sources. Table 2 presents a comparison of these sources for several gases (Rasmussen and Kabel 1975). It is evident that the natural sources of many gases far exceed the manmade sources on a global basis. However, because such natural gases are usually well distributed throughout the atmosphere, their concentration, known as the background concentration, is extremely low. Anthropogenic sources of many pollutants are centered near urban complexes and, therefore, their local pollutant concentrations are higher and may pose major threats to the urban environment. For example, Rasmussen and Kabel (1975) estimate that greater than 90 percent of the global anthropogenic SO_2 is emitted from the Northern Hemisphere. This spatial concentration of pollutant emission sources causes many atmospheric constituents to exceed their natural levels several-fold.

Atmospheric Transport of Pollutants

The fate of a pollutant once emitted into the atmosphere depends on several factors, some meteorological and some a function of the pollutants themselves. It is important to have this information since most sensitive receptor areas are located at considerable distances from the pollutant sources regions.

Several types of meteorological factors influence long distance transport. The prevailing wind regime over much of the eastern U.S. and Canada is one of westerly winds. This pattern is complicated by seasonal trends, such that there is a southerly component in the summer and a northerly component in the winter (Figure 3a, b). "Long-range transport" is facilitated by tall stacks, high wind, and a stable lower atmosphere (i.e., where the temperature increases with altitude). Absence of precipitation also increases the distance of transport. Figure 4 shows isopleths of precipitation for the North American continent. The numbers on the contours represent the average number of centimeters of water falling on the land in one year. The amount of precipitation in any particular locality usually varies from year to year, but over a long period its average is fairly constant. The precipitation patterns shown in Figure 4 partially govern the removal processes of pollutants from the atmosphere.

The properties of the pollutants also will determine their ultimate fate in the atmosphere. Junge (1977) has argued that atmospheric constituents may be put into three categories, each describing the fate of a set of compounds; (1) accumulative gases, (2) gases determined by chemical or physio-chemical equilibria with the earth's surface, and (3) gases and particulate matter (aerosols) determined by steady state conditions of their cycles.

The third category comprises most trace gases and particulate matter and is the prime concern of this report. The atmospheric concentration of these constituents is determined by dynamic processes between sources and sinks. The average atmospheric residence time (T) of a constituent (sometimes also called turnover time) is defined as:

$$\frac{\text{Emission Rate}}{\text{Amount in Atmosphere}} = \frac{\text{Deposition Rate}}{\text{Amount in Atmosphere}} = T \text{ (at steady state)}$$

Pollutant	Major source		Estimated emission kg/yr		Background Concentration µg/m³	Major identified sinks	Residence time[2] days (average)
	Anthropogenic	Natural	Anthropogenic	Natural			
SO_2	Combustion of coal and oil	Volcanoes	130 x 10^9	2 x 10^9	1-4	Scavenging: Chemical reactions; Soil and surface water absorption; Dry deposition, oxidation to SO_4	1-5
	(North America)[3]		16 x 10^9	0.8 x 10^9			
SO_4 (aerosol)	Combustion; SO_2 oxidation	Sea spray			0.5-5	Scavenging; Dry deposition	3-5
H_2S	Chemical processes; Sewage treatment	Volcanoes; Biological decay	3 x 10^9	100 x 10^9	0.3	Oxidation to SO_2	1-3
N_2O	None	Biological decay	None	590 x 10^9	460-490	Photodissociation in stratosphere; Surface water and soil absorption	3,600
NO	Combustion; auto exhaust	Bacterial action in soil; Photodissociation of N_2O and NO_2	53 x 10^9	768 x 10^9	0.3-2.5	Oxidation to NO_2	0.1-5
NO_2	Combustion; auto exhaust	Bacterial action in soils; Oxidation of NO; lightning, fires			2-2.5	Photochemical reactions; Oxidation to nitrate; Scavenging	1-5
NH_3	Coal burning; Fertilizer; Waste treatment	Biological decay	4 x 10^9	170 x 10^9	4	Reaction with SO_2, Oxidation to nitrate; Scavenging	< 7
CO	Auto exhaust and other combustion processes	Oxidation of methane: photodissociation of CO_2; Forest fires; Oceans	360 x 10^9	3000 x 10^9	100	Soil absorption; Chemical oxidation	36
O_3	Electrical discharge, NO_x conversion processes	Tropospheric reactions and transport from stratosphere	(?)	(?)	20-60	Photochemical reactions; Absorption by land surfaces (soil and vegetation;) Surface water	110
Non-reactive hydrocarbons	Auto exhaust; Combustion of fossil fuels	Biological processes in swamps	70 x 10^9	300 x 10^9	CH_4 = 1000 non-CH_4<1	Biological action; Photolysis; Soil and sediment absorption	700
Reactive hydrocarbons	Auto exhaust; Combustion of oil	Biological processes in forests	27 x 10^9	175 x 10^9	<1	Photochemical oxidation	-

From:

[1] Rasmussen et al. 1975. [2] Granat et al. 1976; Junge 1972, 1974, 1977; Kellogg et al. 1972; Liu 1978; Rasmussen et al. 1975. [3] Galloway and Whelpdale 1980; Robinson and Robbins 1970; Rodhe 1978; Stewart et al. 1978; Söderlund and Svensson 1976; Sze 1977.

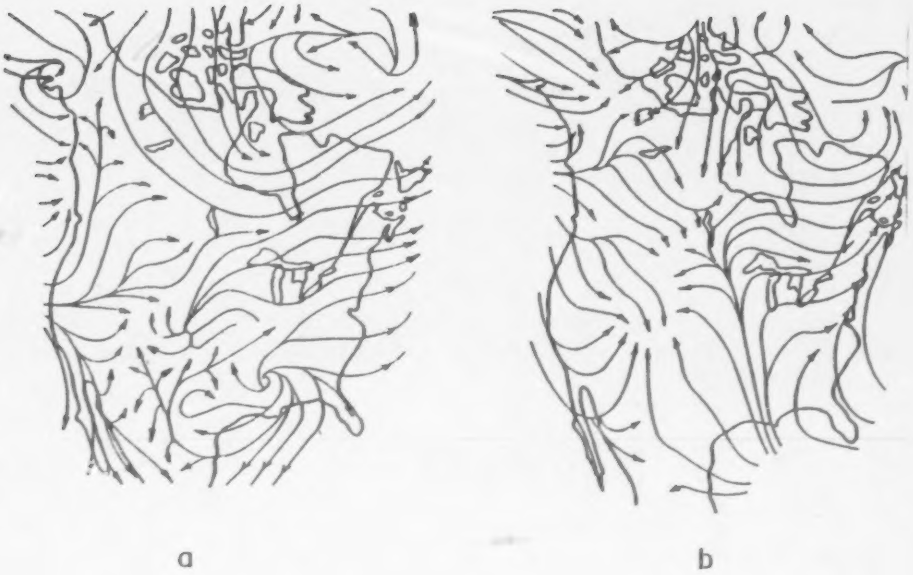
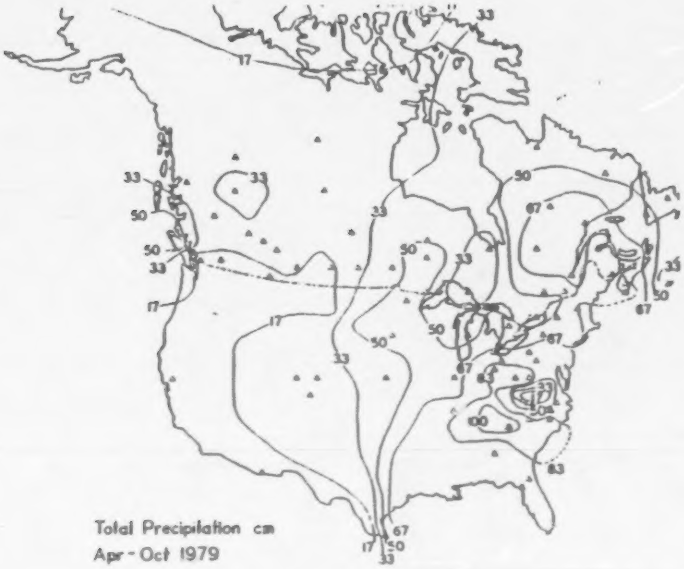
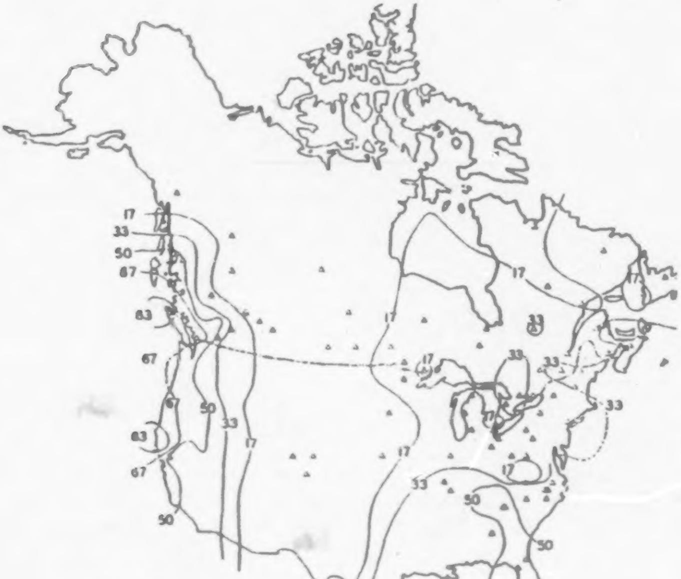


Figure 3a, b. Wind patterns for North America based on surface streamlines for (a) January and (b) July (modified from Bryson and Hare 1974).



Total Precipitation cm
Apr - Oct 1979



Total Precipitation cm
Nov 1979 - March 1980

Figure 4. Seasonal precipitation for North America patterns, total precipitation as water depth (cm), shown for "summer" April-October 1979; "winter" November 1979 - March 1980. Data reporting sites (Δ) are from NADP and CANSAP precipitation monitoring networks (Glass and Brydges 1981).

While pollutants generally are not at a steady state, T is a valuable parameter for predicting whether a constituent is accumulating in the atmosphere. Pollutants such as sulfur and nitrogen oxides, with residence times of just a few days, are particularly important on the regional scale, because these times are comparable to the times typically required for atmospheric transport across eastern North America. A large percentage of compounds with relatively short residence times (a few days) are deposited within tens to hundreds of kilometers from the point of emission. Compounds with longer residence times may travel thousands of kilometers. Galloway and Whelpdale (1980) estimate, for example, that some two-thirds of sulfur emissions in eastern North America are deposited there, the remainder being transported out over the Atlantic Ocean. Table 2 presents typical residence times for other selected parameters.

Atmospheric Removal Processes

Substances transported through the atmosphere are removed via wet and dry processes. There are presently a number of deposition models, both empirical and theoretical, which may be used in delineating pollutant deposition patterns. The suitability of these models depends on the time and space scales of the transport processes under consideration and the complexity of the chemicals of interest. The transport process models require knowledge of the chemical and physical characteristics of the airsheds involved; for example, reaction rates under ambient conditions; the concentration in the solid, vapor, and liquid states; size distributions, morphology, and sorptive characteristics of aerosols; and the vertical, aerial, and temporal variability of these parameters.

Particles and unreactive gases in air may be removed by rainout (in-cloud processes) and washout (below-cloud removal). The wet flux of these substances is a function of their concentration in precipitation and the amount of precipitation. The particle washout ratio has been computed by several authors for different chemicals (see, for example, Slinn _et al_. 1978). Slinn _et al_. (1978) also have summarized data on enhanced solubility coefficients for reactive gases. These gases include SO_2, where the dissolution, hydrolysis and oxidation to sulfuric acid are considered.

Accurate and direct measurements of dry deposition, both for aerosols and gases, are not possible at present (Hicks and Williams 1980). The mass transfer is especially difficult to estimate for trace chemicals because long sampling times are required (often greater than 24 hours) and meteorological conditions may change drastically during such a sampling interval. Dryflux estimates will undoubtedly change in the future as deposition measurement techniques and models improve. At the present time it seems that the best experimental strategy is to collect accurate data for atmospheric constituents with the best possible time resolution, at an appropriate reference height, and with as much meteorological information as possible.

Several approaches are available for indirectly calculating mass transfer of aerosols to the earth's surface. The most popular approach has been to use the relation by Chamberlain (1966):

$$F = \bar{V}_D C_z \tag{1}$$

where F = flux, V_D = deposition velocity, and C_z = pollutant concentration at a certain reference height. Deposition velocity data, determined by wind tunnel experiments for several particle diameters, roughness lengths, and friction velocities, have been furnished by Sehmel and Sutter (1974), Cawse (1974), and Möller and Schumann (1970). The data, which has been summarized by Gatz (1974), represent time-averaged deposition velocities for a variety of meteorological conditions and thus do not necessarily give realistic values for aerosol depositions to water. Sievering (1980) has used the profile method for estimating fluxes across the air/water interface. Hicks and Williams (1980) have proposed a new spray capture model, indicating that very little (if any) transport is possible during calm conditions. Slinn (1980) has proposed a more sophisticated resistance model where aerosol growth in the surface layer is included. Sehmel and Hodgson (1974) have presented a model based on dimensionless integral mass transfer resistances. Surface integral resistances were evaluated with deposition velocities of monodispersed aerosols determined in wind tunnel experiments.

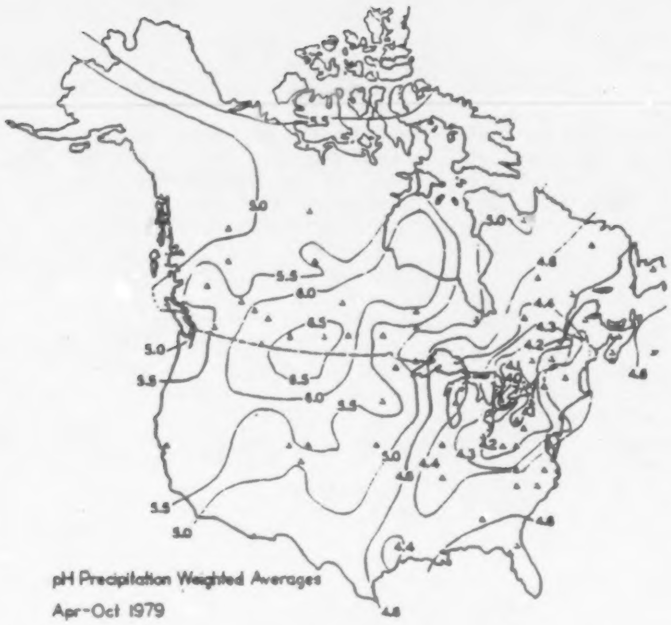
Similar models are also available for gaseous deposition to various surfaces. Whelpdale (1979), Garland (1979), and Liss and Slater (1974) have devised models based on resistance of transfer to various surfaces, such as grass, snow, water, and forest canopies. These models usually include an aerodynamic, stagnant film, and stomatal (for vegetation) resistance. The same caveats on these models are necessary as those applied to dry particle deposition.

The relative importance of each process, i.e., dry vs. wet deposition, is still being evaluated. Although the results are not fully conclusive, modeling and mass balance studies indicate wet and dry deposition of sulfur compounds are of about equal importance in northern Europe and North America (Fowler 1980, Harvey et al. 1981). Dry deposition seems to be of lesser importance in remote areas. Harvey et al. (1981) conclude that dry deposition is relatively more important in areas like the Ohio Valley whereas the opposite is true in remote Canadian Shield lakes.

Alteration of Precipitation Quality

The seasonal quantity and quality of precipitation are important for determining the potential for acid precipitation impacts on the environment (Figure 5). Acid pollutants accumulating in the snowpack have a higher potential for causing deleterious effects on organisms and habitats in areas with higher amounts of snowfall than in areas with lower amounts of snow accumulation. This is due to the rapid flushing of accumulated acid during snowmelt. Large storms, on the other hand, tend not to have as low a pH for the entire rainfall as do light rains. Thus, the distribution of precipitation during the year, the temporal behavior of rainfall, and the location of pollution sources within rainfall pathways are linked to the potential for damage to the aquatic ecosystems. In addition, many areas in the East with the greatest annual precipitation have the least buffering capacity in soils and waterways.

All precipitation contains a wide variety of chemical constituents from sources such as sea spray, dust particles, and the natural cycling of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4.6
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4.2
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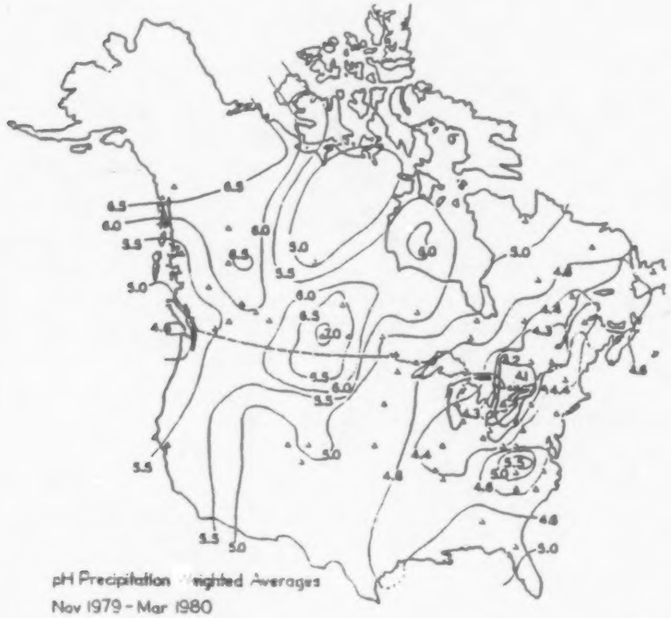
pH Precipitation Weighted Averages
Apr-Oct 1979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4.2
4.1
4.4
4.3
4.6
5.5
5.0
4.6
4.4
4.6
5.5
5.5
5.0
4.6
5.0

pH Precipitation Weighted Averages
Nov 1979 - Mar 1980

Figure 5. Seasonal pH of precipitation, volume weighted averages "summer" April - October 1979; "winter" November 1979 - March 1980. Data reporting sites (Δ) are from NADP and CANSAP precipitation monitoring networks (Glass and Brydges 1981).

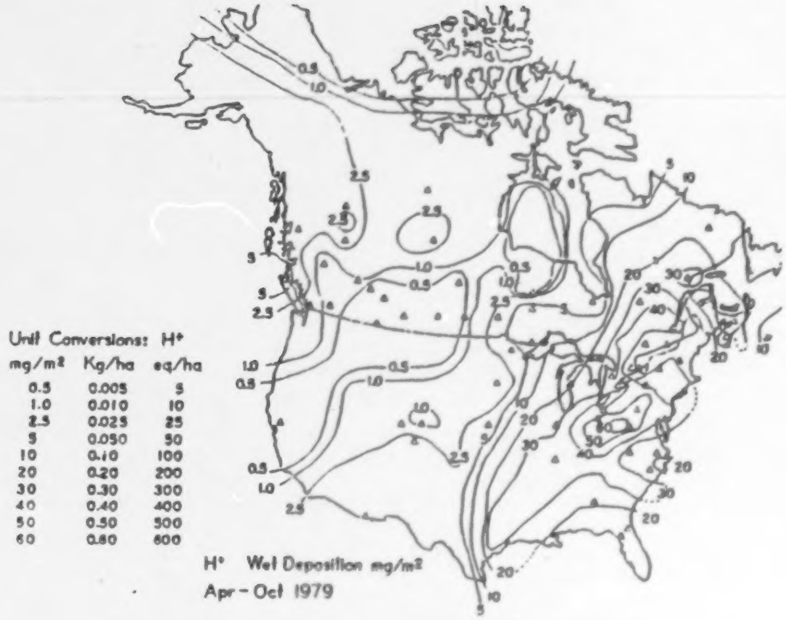
carbon, nitrogen and sulfur. The discharge of wastes to the atmosphere increases the amounts of compounds containing elements such as nitrogen, carbon and sulfur, and adds to the variety of compounds, such as PCBs and PAHs, and heavy metals, which are found in rainfall. The four ions usually of most importance to rainfall acidity are: hydrogen (H), ammonium (NH_4), nitrate (NO_3) and sulfate (SO_4). Other ions, e.g., calcium, may be important under some conditions. Some of the nitrogen and sulfur-containing pollutants are oxidized to nitric and sulfuric acids, so that the acid content of precipitation is mainly a secondary result of the primary emissions.

Distilled water in equilibrium with atmospheric carbon dioxide has a pH value of about 5.6. Results of CANSAP and NADP monitoring presented in Figure 5 show large areas of North America receive precipitation with a pH at or above 5.6, but much of the east is considerably below 5.6. The low pH results in elevated deposition of acids to the surface as shown in Figure 6a, in contrast to deposition which would occur if the precipitation had a pH of 5.6 (Figure 6b).

Table 3 lists the concentrations of the four major ions in bulk precipitation and total bulk deposition for various sites in North America. Precipitation at pH 5.6 has a hydrogen ion content of about 2.5 μeq/ℓ (microequivalents/liter). It is evident that the most westerly study area (see Figure 2), the Experimental Lakes Area, has an acid concentration of about four times this value, while Dorset and Hubbard Brook are about 30 times this value. Sulfate is the dominant anion in terms of eq/ℓ (equivalents/liter). In the wet precipitation at Kejimkujik National Park, Nova Scotia, the most easterly study area (see Figure 2), the pH is about 4.6 while sulfate is the second highest anion, surpassed by chloride (41 μeq/ℓ), which is a reflection of the strong maritime influence on the precipitation in Nova Scotia. Thus, although the pH of rainfall can vary considerably for reasons of its natural constituents, a pH of 5.6 is representative of both large pollution-free storms and of the relatively pollutant-free regions of North America.

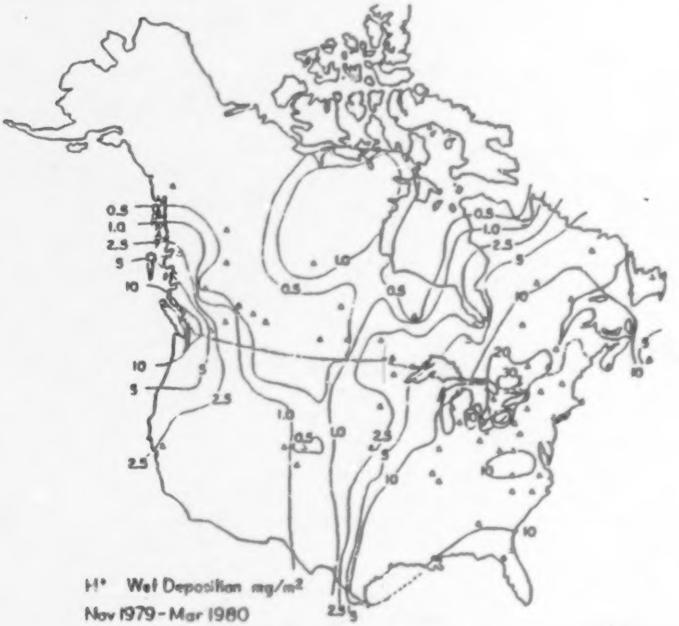
Figures 7 through 14 show the summer (April to October inclusive) and winter (November to March inclusive) deposition of sulfate, ammonium, nitrate, chloride, calcium, magnesium, sodium, and potassium, respectively. These periods are selected to coincide with rain and snow seasons along the U.S./Canada boundary. The sulfate deposition is about 3 times greater in summer than in winter, particularly in the areas of greatest deposition in eastern North America. This is consistent with seasonal sulfur emissions (Work Group 2 report). Ammonium deposition also tends to be greater in the summer months, although some areas have similar winter and summer values. Nitrate deposition is similar to ammonium deposition, with a tendency toward higher values in the summer, with western areas having similar winter and summer values.

The alkali and alkaline earth metals (Figures 11 to 14) show major influences due to inputs from coastal and oceanic areas, especially in the mid-latitude regions of North America. However there are also significant regional sources for those metals, apparently from wind-blown dust in the arid and plains regions of central North America. These elevated levels of sodium, potassium, calcium, and magnesium also coincide with the high pH values, Figure 5, indicating that the input of these alkaline substances acts to neutralize and, in many instances, to raise the pH of precipitation above that expected for background levels.



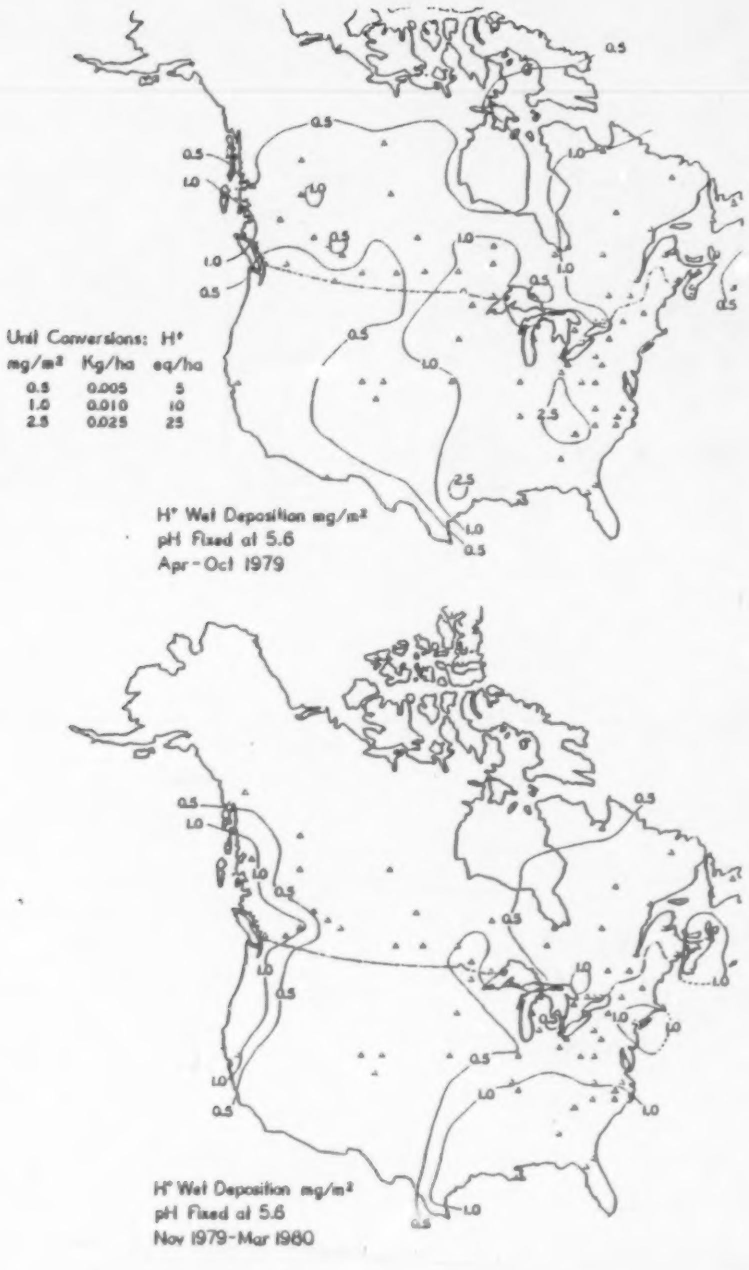
Unit Conversions: H⁺		
mg/m²	Kg/ha	eq/ha
0.5	0.005	5
1.0	0.010	10
2.5	0.025	25
5	0.050	50
10	0.10	100
20	0.20	200
30	0.30	300
40	0.40	400
50	0.50	500
60	0.60	600

H⁺ Wet Deposition mg/m²
Apr - Oct 1979
0.5
1.0
2.5
5
10
20
30
40
50



H⁺ Wet Deposition mg/m²
Nov 1979 - Mar 1980
0.5
1.0
2.5
5
10
20
30

Figure 6a. Seasonal H wet deposition for North America, mg/m², "summer" April - October 1979; "winter" November 1979 - March 1980. Data reporting sites (Δ) are from NADP and CANSAP precipitation monitoring networks (Glass and Brydges 1981).


0.5
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1.0
0.5
1.0
1.0
1.0
0.5
0.5
0.5
1.0
2.5
2.5
1.0
0.5
0.5
Unit Conversions: H⁺
mg/m² Kg/ha eq/ha
0.5 0.005 5
1.0 0.010 10
2.5 0.025 25
H⁺ Wet Deposition mg/m²
pH Fixed at 5.6
Apr-Oct 1979
0.5
1.0
1.0
0.5
0.5
1.0
0.5
1.0
1.0
1.0
1.0
0.5
1.0
0.5
1.0
1.0
H⁺ Wet Deposition mg/m²
pH Fixed at 5.6
Nov 1979-Mar 1980
0.5
1.0

Figure 6b. Seasonal calculated H wet deposition mg/m², for North America assuming background pH of 5.6, for "summer" April - October 1979; "winter" November 1979 - March 1980. Data reporting sites (Δ) are from NADP and CANSAP precipitation monitoring networks (Glass and Brydges 1981).

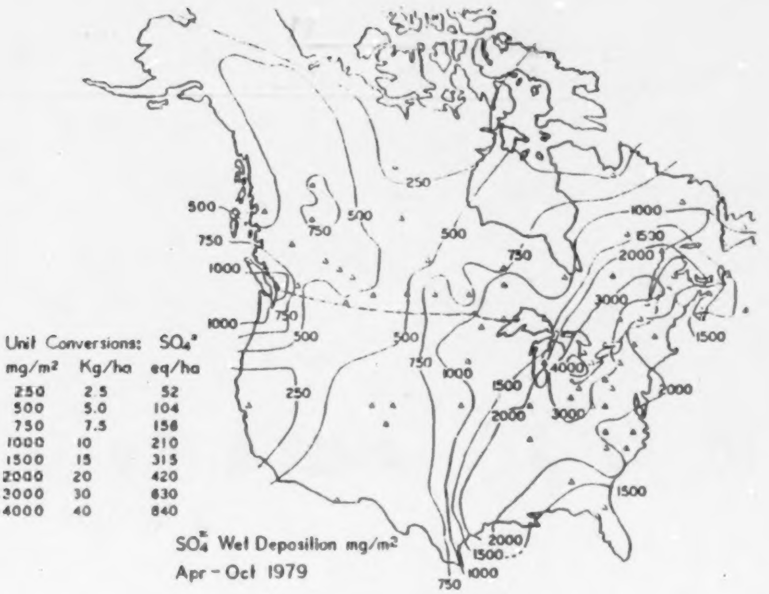
Table 3. CONCENTRATIONS IN BULK DEPOSITION AND TOTAL BULK DEPOSITION OF FOUR IONS AT FIVE CALIBRATED WATERSHED STUDIES.

	E.L.A.[1], Ontario	Dorset[2], Ontario	Hubbard Brook[3], New Hampshire	Kejimkujik* Park[4], Nova Scotia	Sagamore Lake[5], New York
Concentrations in Bulk Deposition (μeq/ℓ)					
H	11	70-90	72-4	24	-
NH_4	21	34-36	12.2	4.4	-
NO_3	18.5	36-41	23.7	12.4	-
SO_4	30	77-89	60.3	33(28.5)	-
Total Bulk Deposition in meq m^{-2} yr^{-1} from bulk deposition					
H	10	55-58	96	34	80-95
NH_4	-	22-28	16	6	20-26
NO_3	-	25-34	30.6	17	37-50
SO_4	20.7	62-64	79	46(40)	81-95

* Wet deposition only, ( ), indicating excess sulfate.

FROM: [1] Schindler et al. 1976
[2] Scheider et al. 1979a
[3] Likens et al. 1977
[4] Kerekes 1980
[5] Johannes and Altwicker 1980

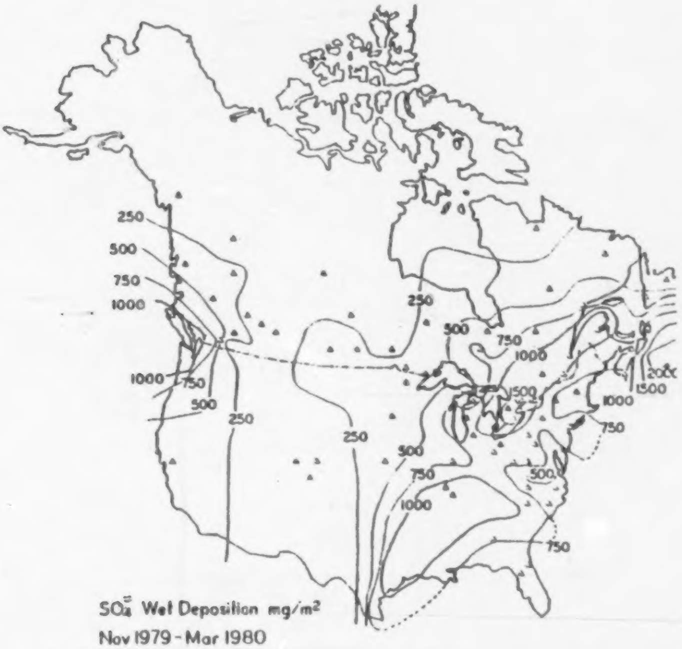
NOTE: differences in values for areas, compared to the isoplot figures are due to year to year variations.


500
750
1000
1000
750
500
250
500
750
250
500
750
1000
1500
2000
3000
4000
1000
1500
2000
3000
2000
1500
1500
2000
1500
750
1000

Unit Conversions: $SO_4^=$

mg/m²	Kg/ha	eq/ha
250	2.5	52
500	5.0	104
750	7.5	156
1000	10	210
1500	15	315
2000	20	420
3000	30	630
4000	40	840

$SO_4^=$ Wet Deposition mg/m²
Apr – Oct 1979


250
500
750
1000
1000
750
500
250
250
250
500
750
1000
1500
2000
1500
1000
750
300
750
1000
500
750

$SO_4^=$ Wet Deposition mg/m²
Nov 1979 - Mar 1980

Figure 7. Seasonal SO_4 wet deposition, mg/m², for North America, for "summer" April - October 1979; "winter" November 1979 - March 1980. Data reporting sites (Δ) are from NADP and CANSAP precipitation monitoring networks (Glass and Brydges 1981).

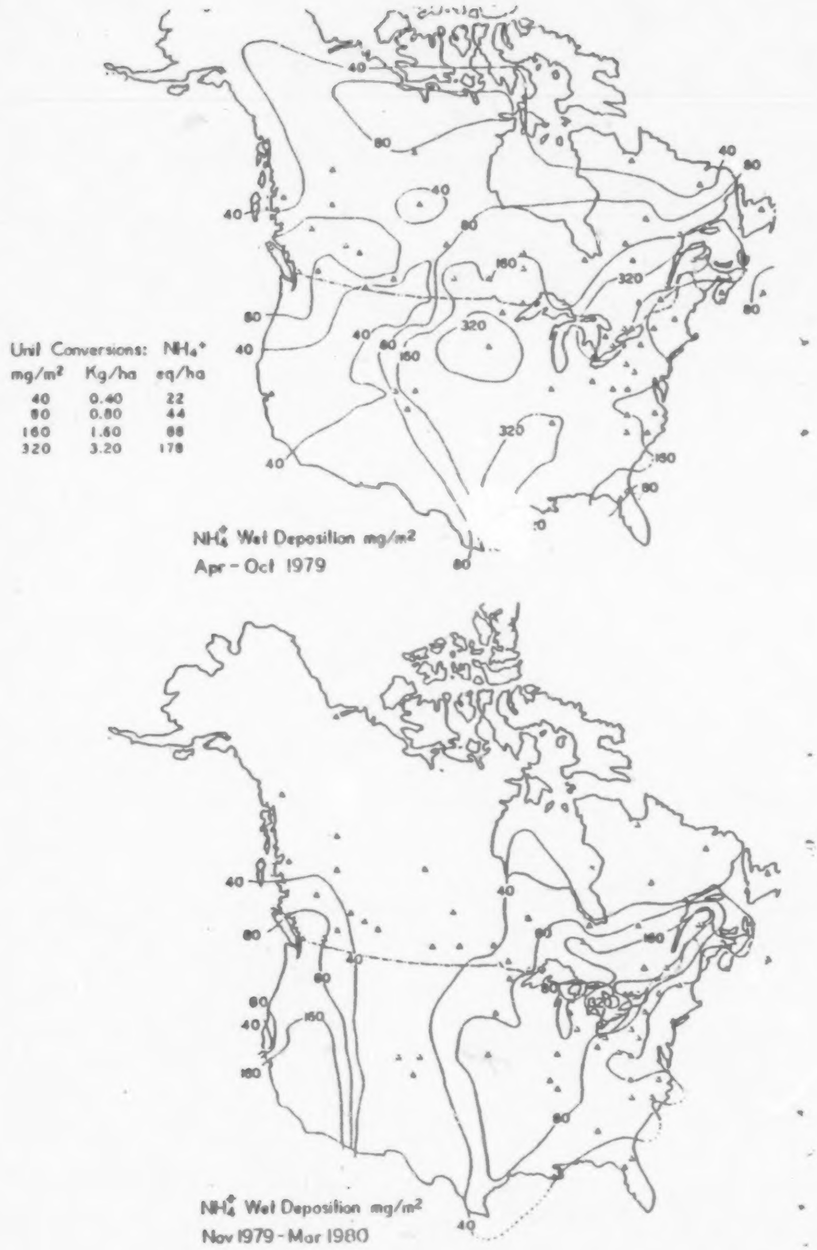
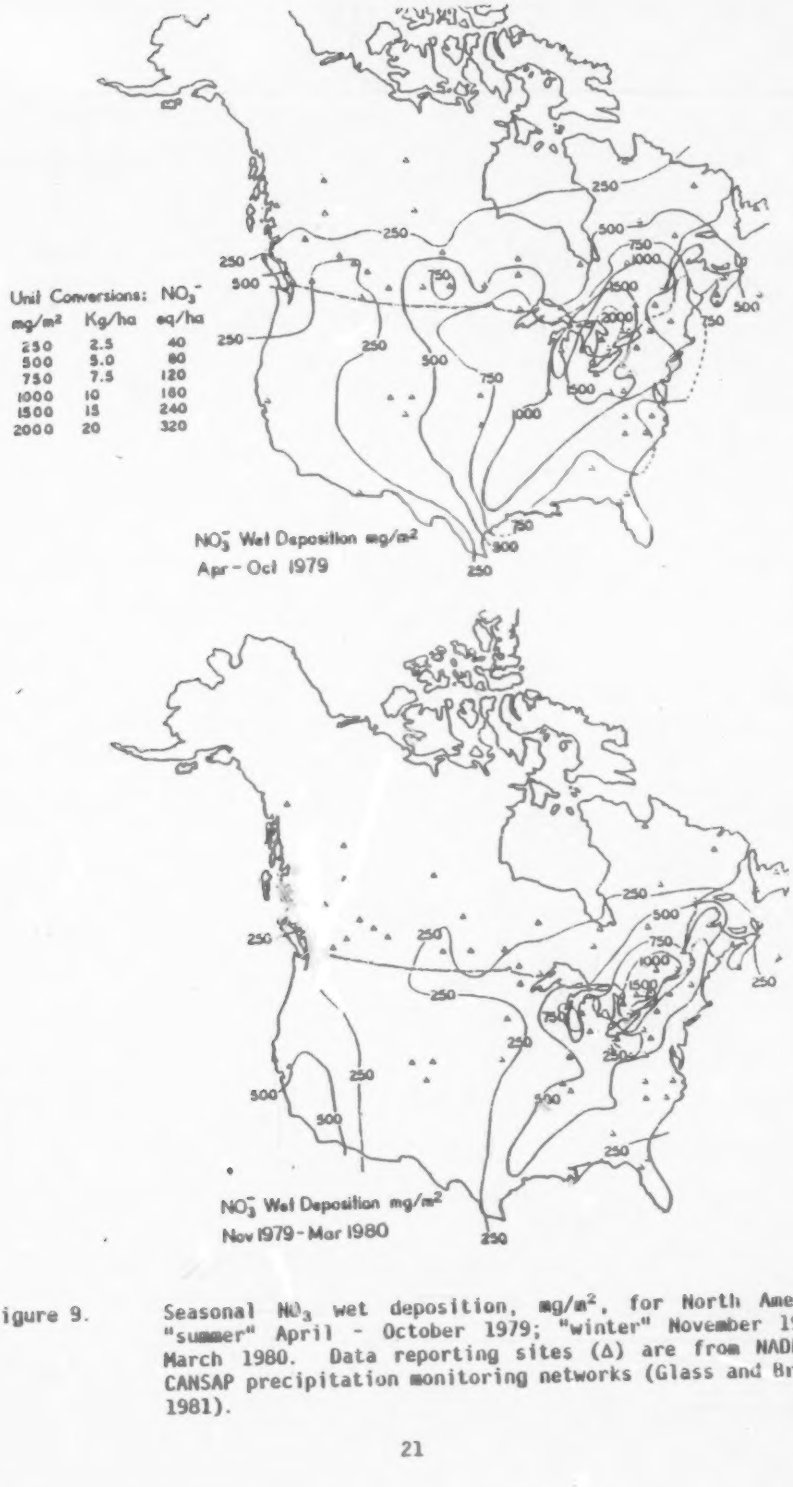

Unit Conversions: NH$_4^+$
mg/m² Kg/ha eq/ha
40 0.40 22
80 0.80 44
160 1.60 88
320 3.20 178
40
80
160
320
NH$_4^+$ Wet Deposition mg/m²
Apr - Oct 1979
NH$_4^+$ Wet Deposition mg/m²
Nov 1979 - Mar 1980

Figure 8. Seasonal NH_4 wet deposition, mg/m², for North America, "summer" April - October 1979; "winter" November 1979 - March 1980. Data reporting sites (Δ) are from NADP and CANSAP precipitation monitoring networks (Glass and Brydges 1981).

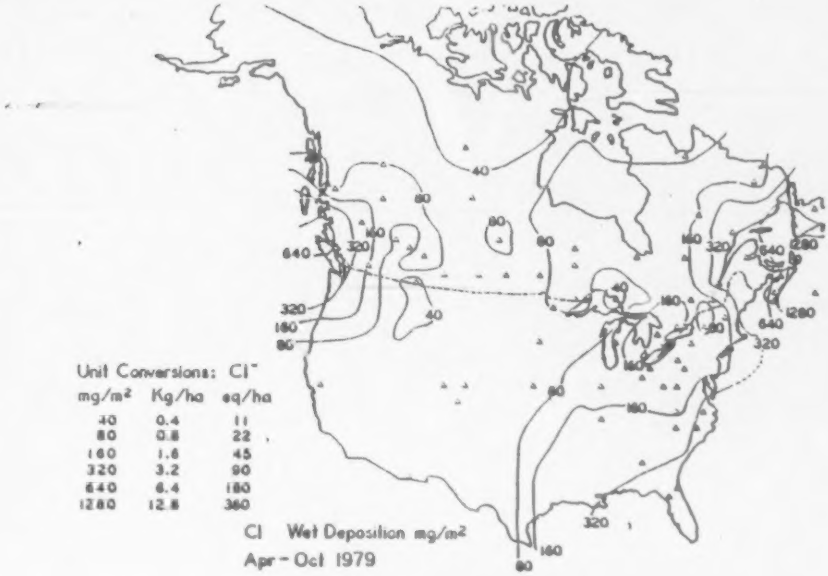


250
500
750
1000
1500
2000
NO$_3^-$ Wet Deposition mg/m^2
Apr - Oct 1979
NO$_3^-$ Wet Deposition mg/m^2
Nov 1979 - Mar 1980

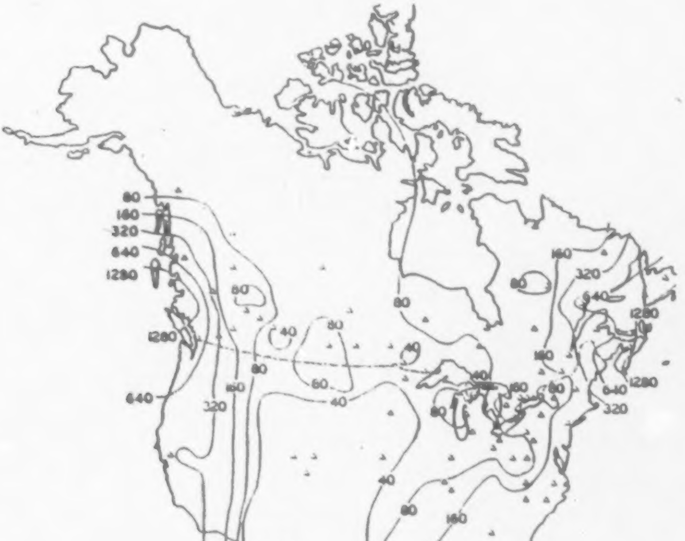
Unit Conversions: NO$_3^-$

mg/m^2	Kg/ha	eq/ha
250	2.5	40
500	5.0	80
750	7.5	120
1000	10	160
1500	15	240
2000	20	320

Figure 9. Seasonal NO$_3$ wet deposition, mg/m^2, for North America, "summer" April - October 1979; "winter" November 1979 - March 1980. Data reporting sites (Δ) are from NADP and CANSAP precipitation monitoring networks (Glass and Brydges 1981).

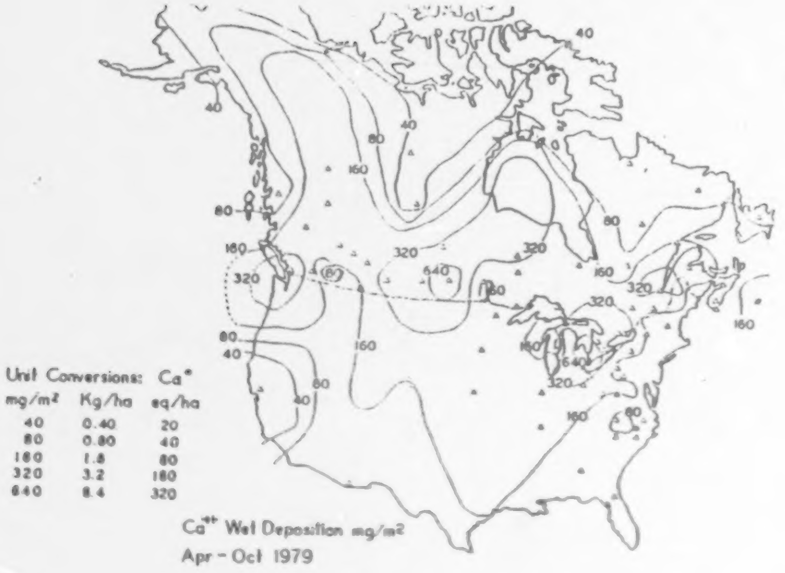

Unit Conversions: Cl⁻
mg/m² Kg/ha eq/ha
40 0.4 11
80 0.8 22
160 1.6 45
320 3.2 90
640 6.4 180
1280 12.8 360
40
80
160
320
640
1280

Cl Wet Deposition mg/m²
Apr - Oct 1979


80
160
320
640
1280
40
80
160
320
640
1280

Cl⁻ Wet Deposition mg/m²
Nov 1979 - Mar 1980

Figure 10. Seasonal Cl wet deposition, mg/m², for North America, "summer" April - October 1979; "winter" November 1979 - March 1980. Data reporting sites (Δ) are from NADP and CANSAP precipitation monitoring networks (Glass and Brydges 1981).


40
40
80
40
80
160
80
160
320
320
640
160
320
80
160
320
320
160
160
160
640
320
160
80
80
40
40
Ca⁺⁺ Wet Deposition mg/m²
Apr - Oct 1979

Unit Conversions: Ca⁺

mg/m²	Kg/ha	eq/ha
40	0.40	20
80	0.80	40
160	1.6	80
320	3.2	160
640	6.4	320

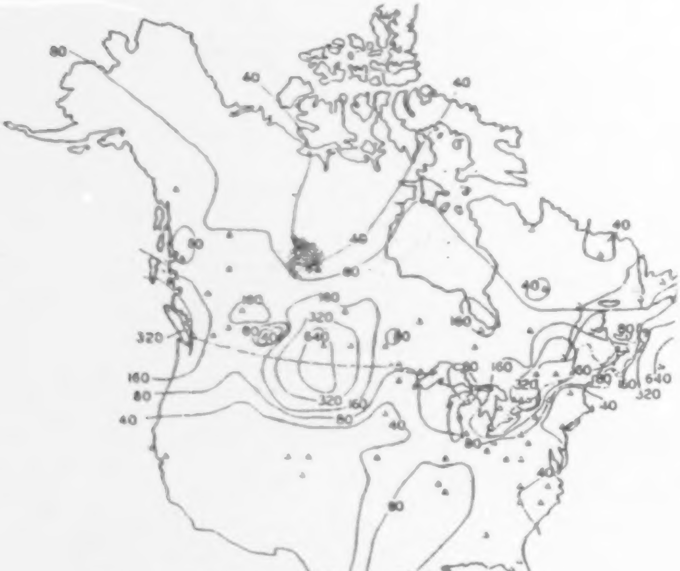
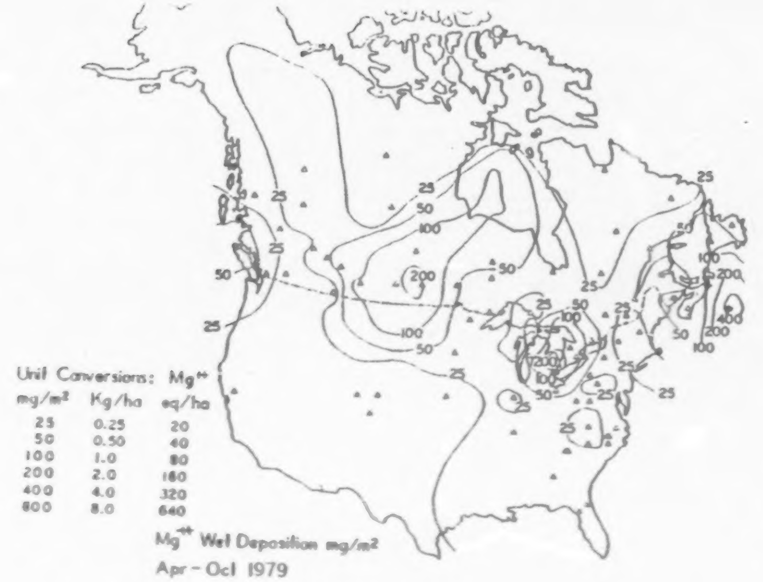

80
40
40
40
80
40
80
40
160
160
320
80
40
640
80
160
320
160
80
40
320
160
80
40
160
320
80
160
640
320
40
80
40
80
80
40
Ca⁺⁺ Wet Deposition mg/m²
Nov 1979 - Mar 1980

Figure 11. Seasonal Ca wet deposition, mg/m², for North America, "summer" April - October 1979; "winter" November 1979 - March 1980. Data reporting sites (Δ) are from NADP and CANSAP precipitation monitoring networks (Glass and Brydges 1981).


Mg++ Wet Deposition mg/m²
Apr - Oct 1979
25
50
100
200
400

Unit Conversions:		Mg++
mg/m²	Kg/ha	eq/ha
25	0.25	20
50	0.50	40
100	1.0	80
200	2.0	160
400	4.0	320
800	8.0	640

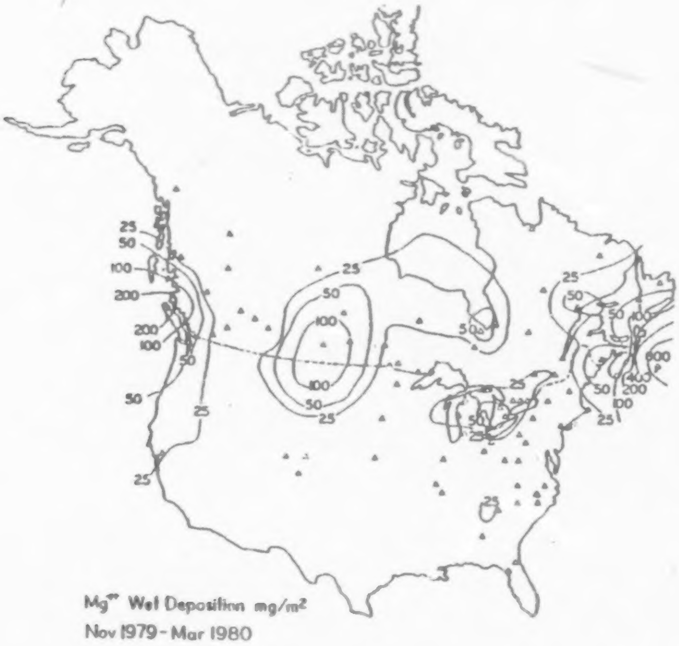
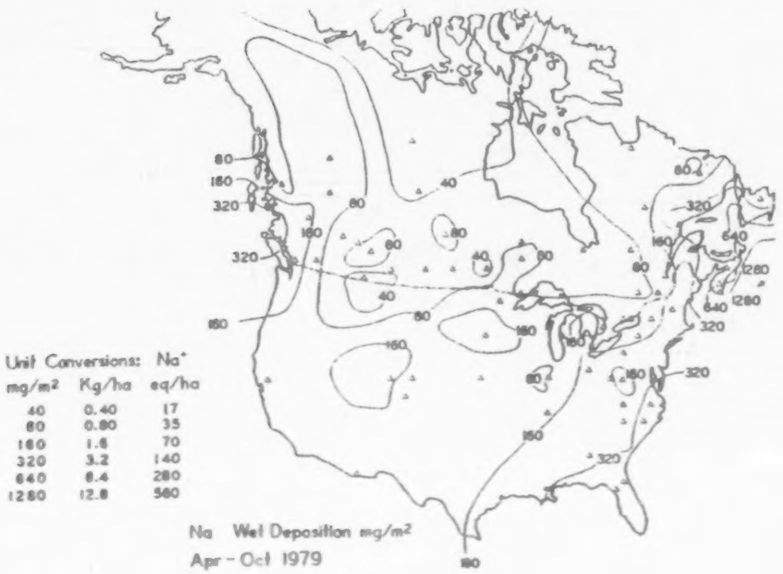
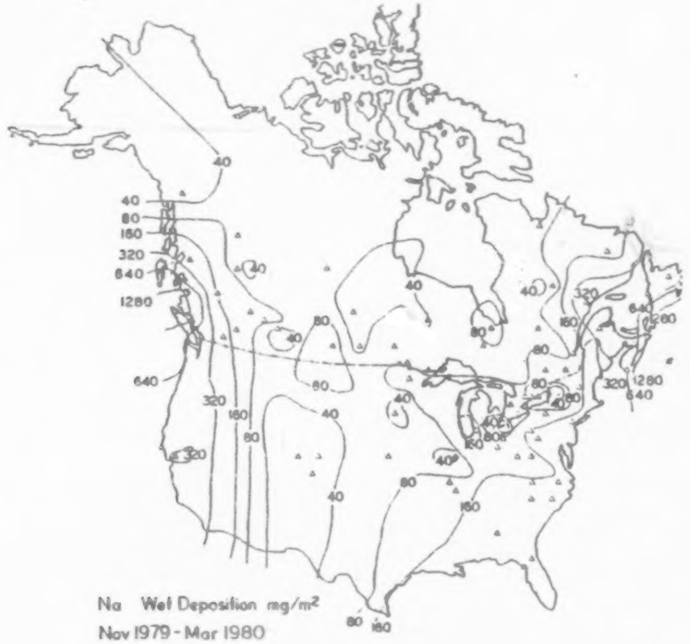

Mg++ Wet Deposition mg/m²
Nov 1979 - Mar 1980
25
50
100
200
800

Figure 12. Seasonal Mg wet deposition, mg/m², for North America, "summer" April - October 1979; "winter" November 1979 - March 1980. Data reporting sites (Δ) are from NADP and CANSAP precipitation monitoring networks (Glass and Brydges 1981).


80
160
320
320
160
40
80
160
80
40
40
80
40
80
160
160
80
80
160
320
160
80
320
640
1280
1280
640
320
160
320
160
320
160

Unit Conversions: mg/m²	Kg/ha	Na⁺ eq/ha
40	0.40	17
80	0.80	35
160	1.6	70
320	3.2	140
640	6.4	280
1280	12.8	560

Na Wet Deposition mg/m²
Apr - Oct 1979


40
40
80
160
320
640
1280
40
640
320
160
80
40
80
40
40
80
40
40
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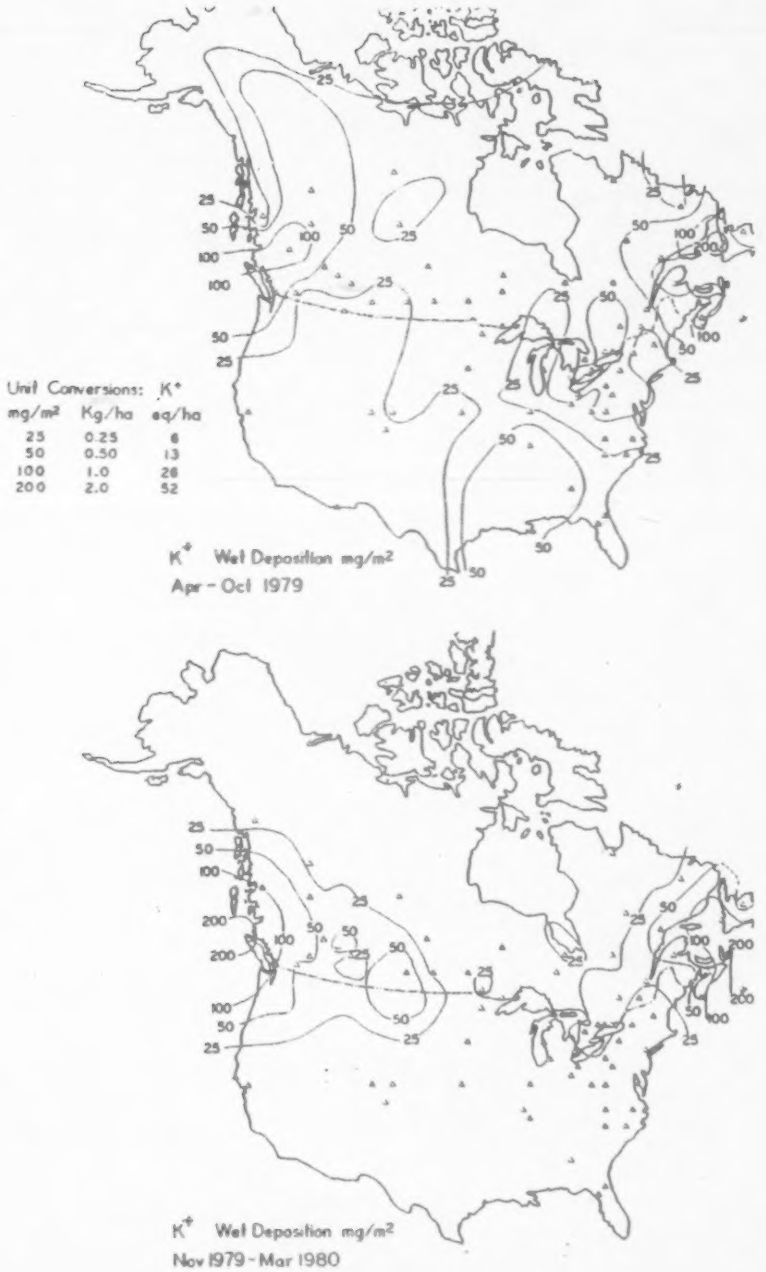
320
640
1280
160
80
80
40
320
1280
640
40
40
80
40
80
160
320
40
80
160
80
160

Na Wet Deposition mg/m²
Nov 1979 - Mar 1980

Figure 13. Seasonal Na wet deposition, mg/m², for North America, "summer" April - October 1979; "winter" November 1979 - March 1980. Data reporting sites (Δ) are from NADP and CANSAP precipitation monitoring networks (Glass and Brydges 1981).


K+ Wet Deposition mg/m2
Apr - Oct 1979
K+ Wet Deposition mg/m2
Nov 1979 - Mar 1980
25
50
100
200

Unit Conversions: K+

mg/m²	Kg/ha	eq/ha
25	0.25	6
50	0.50	13
100	1.0	26
200	2.0	52

Figure 14. Seasonal K wet deposition, mg/m², for North America, "summer" April - October 1979; "winter" November 1979 - March 1980. Data reporting sites (Δ) are from NADP and CANSAP precipitation monitoring networks (Glass and Brydges 1981).

ELEMENT FLUXES AND GEOCHEMICAL ALTERATIONS OF WATERSHEDS

This section is concerned with the fate of ions deposited from the atmosphere and the resulting geochemical alteration of watersheds and surface waters.

The Hydrogen Ion

The hydrogen ion driving most chemical weathering reaction is supplied from both external and internal sources. The external source is the acid supplied by atmospheric deposition (meteorological input); the internal source stems from various biologic and chemical processes occurring within the soil zone. The average external net annual input of hydrogen ion equivalent, observed at the Hubbard Brook watershed over the 1963-74 decade, was 86.5 ± 3.3 meq m^{-2} yr^{-1} (milli-equivalents/square meter/year) (Likens et al. 1977). If this were the only source of H ions at Hubbard brook (and the ecosystem were in a steady state), one might expect this value for hydrogen fixation to be more or less balanced by the net rate at which ionic Ca, Mg, K, Na, and Al are leached from the system. In fact, there are more of these cations removed from the ecosystem each year than there are external hydrogen ions to replace them. The difference is statistically significant, and implies the action of internally generated H and/or an underestimate of dry deposition. Internal sources of H at Hubbard Brook are identified as: (1) nitrogen compounds, particularly NH_4 inputs; (2) reduced carbon oxidized in the soil zone; (3) organic acids, such as citric, tartaric, tannic, and oxalic acid, produced by biologic activity within the soil zone; and (4) small amounts of sulfide minerals in the bedrock, which are subject to oxidation, with concomitant production of sulfuric acid.

The amounts of hydrogen ion being deposited from acid precipitation generally are in the range of 50-100 meq m^{-2} yr^{-1} for the most heavily loaded areas, corresponding to 25 and 50 kg ha^{-1} yr^{-1} (kilograms/hectare/year) of calcium carbonate. Limestone soils can neutralize this amount of acid for an indefinite time, resulting in only a slight increase in total runoff of calcium and magnesium salts relative to amounts in the soil. However, in areas of Precambrian shield bedrock (Eastern Canada and parts of adjoining U.S.), the amounts of salts and alkaline materials being leached are in the order of 10 to 100 meq m^{-2} yr^{-1}. Hydrogen ion loadings are of the same order of magnitude in these areas and thus influence normal weathering processes and modify the quality of surface runoff. For example, some of the acid results in leaching of such cations as aluminum, iron, and manganese.

In most parts of the Precambrian shield, hydrogen ions from rainfall are neutralized during most of the year. Retention or neutralization of hydrogen ions deposited in bulk deposition has been measured at 88, 94, and 98 percent, on an annual basis, at Experimental Lakes Area, Hubbard Brook, and Dorset, respectively (Schindler et al. 1976, Likens et al. 1977, Scheider et al. 1979a). Hydrogen ions deposited in snow tend to be stripped from snow crystals early in the spring snowmelt process, and much of the total annual H export from the watershed occurs during a brief period in the spring. The large volume of water, coupled with less opportunity for partial infiltration and interaction with soil, results in "shock level" concentrations of acid to streams and surface waters of lakes (Schofield 1980). Hultberg (1976) reported on such pH depressions in lakes and rivers in Sweden and concluded that the water quality conditions were lethal to fish.

Nitrate and Ammonium Ions

The atmospheric deposition of nitrate ion tends to range from 1/3 to 1/2 of the rate of sulfate deposition in eastern North America, to about 60% of acid fractions in rainfall in the western United States (Liljestrand and Morgan 1978). The significance of the nitrogen component of acidic deposition is difficult to interpret with any broad generality, since it has more complex response processes than those of sulfate.

The molecular forms of nitrogen deposited in acidic deposition can result in either acidification or neutralization of surface waters. Nitrogen, as nitrate ions (NO_3), can be incorporated directly by vegetation, and the resulting reactions release hydroxyl ions (OH) into the environment (Figure 15). The hydroxyl ions raise the pH of the soil and water, or neutralize the hydrogen ions of the nitric acid. Natural decomposition of nitrogenous plant materials releases hydrogen ions, but net accumulation of plant tissue dominates in most ecosystems (Bormann and Likens 1979). Hence, net production of neutralizing capacity from nitrate addition is often dominant (see data from Harvey et al. 1981; Brewer and Goldman 1976). This is particularly significant where forest harvest, rather than decomposition, removes plant materials, because the neutralizing portion of the cycle is left in the system, and a portion of the acidification source (decomposition) is removed.

Ammonium salts are deposited with the sulfate particulates in both dry and wet deposition. Ammonium is a source of hydrogen ions (Figure 15) when the nitrogen is utilized by plants. This release of hydrogen ions can be a significant source of acidification in poorly buffered soils and surface waters. The uptake and retention of nitrate and ammonium by seven forested watersheds are summarized in Table 4.

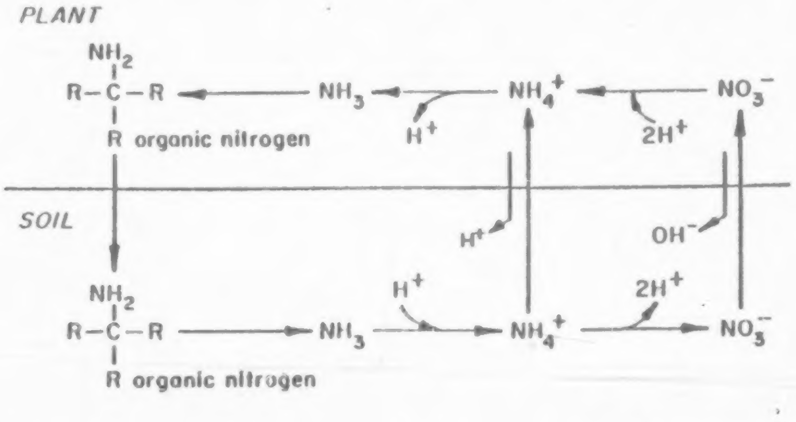


Figure 15. Simplified nitrogen cycle showing chemical changes caused by plant and soil processes (from Reuss, 1976).

Table 4. THE UPTAKE OF NITRATE, AMMONIUM ION, AND TOTAL NITROGEN BY FORESTED WATERSHEDS IN FIVE CALIBRATED WATERSHED STUDIES.

Substance	% Retention in the watershed on an annual basis						
	E.L.A.[1], Ontario	Dorset[2], Ontario	Hubbard Brook[3], New Hampshire	Kejimkujik Park[4], Nova Scotia	Sagamore Lake[5], New York	Woods Lake[5], New York	Panther Lake[5], New York
NO_3	-	75	15	99	43	70	15
NH_4	-	95	89	98	90	90	90
Total Nitrogen	81-90	-	-	-	-	-	-

From: [1] Schindler et al. 1976

[2] Scheider et al. 1979a

[3] Likens et al. 1977

[4] Kerekes 1980

[5] Galloway et al. 1980 (figures estimated from published bar graphs)

As with acid sulfates, nitric acid (nitrates) and ammonium salts can be stored in the snowpack of northeastern North America and released as acid components to aquatic habitats during spring snowmelt. During the growing season, however, both terrestrial and aquatic vegetation take up nitrate, and may, therefore, be partially responsible for the observed decreases in acidity in aquatic ecosystems. The fact that nitrate tends to be in greater quantity in precipitation than ammonium ions, and that both are largely taken up by vegetation, results in a net production of alkalinity.

Sulfate

Sulfur, like nitrogen, is an essential plant nutrient, but it is usually in adequate supply for plant growth in soils and is recycled through normal ecosystem cycling processes. Sulfate ions can be adsorbed by soils or reduced, mainly by bacterial action, which consumes acid and raises the pH of the soil-water environment. The reduced sulfide forms S(-II) can be oxidized back to sulfate, resulting in the production of hydrogen ions. Sulfate, then, can react in ways analogous to nitrogen, and its influence on acidification can also be analogous (Figure 16).

In spite of many possible reactions, much of the SO_2 and SO_4 deposited in acidic deposition is not retained in Precambrian shield watersheds; thus, sulfate tends to be the anion balancing the transport of H and other cations in surface water and shallow groundwater. The amount of SO_4 in runoff from the Shield areas is very close to the amount deposited. At the Experimental Lakes Area in Ontario, Schindler et al. (1976) found virtually 100% of the atmospheric SO_4 input in the runoff. Likens et al. (1977) found 67% of the total input in runoff at Hubbard Brook, New Hampshire, and Dillon et al. (1980) found 25% more SO_4 in runoff from four watersheds than was measured in the bulk deposition. Kerekes (1980) reported that outputs of sulfate were about 80% of the annual inputs for the Lower Mersey River system in Nova Scotia. At the Sagamore Lake Study area, Galloway et al. (1980) observed that sulfur inputs and outputs were in balance for two lake/watershed systems while a third watershed may have been accumulating some sulfur. In certain kinds of soils, such as those common in the southeastern U.S., sulfate may be retained in the soil by physical adsorption processes (D.W. Johnson, personal communication). This will have the very important effect of retarding the movement of cations, including H+, from the soil to aquatic systems.

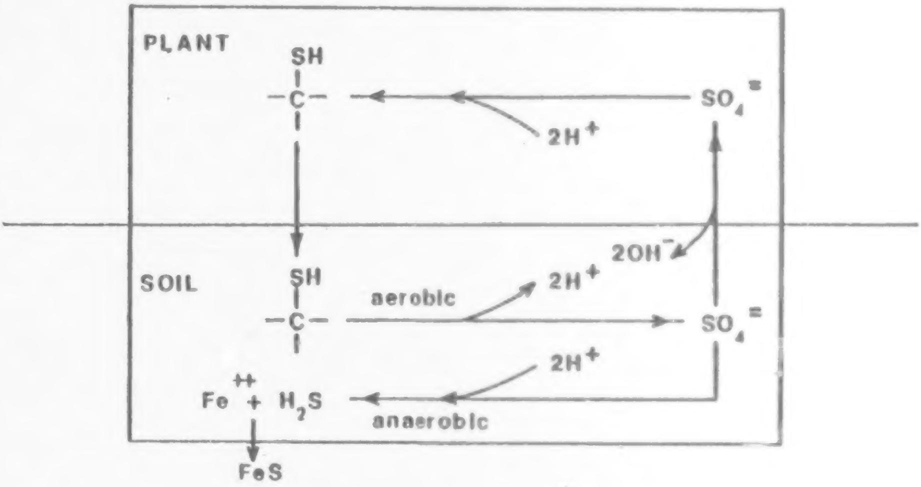


Figure 16. Simplified sulfur cycle showing chemical changes caused by plant and soil processes (modified from Reuss, 1976).

Aluminum and Other Metals

One of the indirect effects of soil acidification is the mobilization of aluminum. The solubility of this metal is pH dependent, and increases with increasing acidity, as well as increasing alkalinity (Figure 17). Several reports have documented elevated aluminum concentrations in the surface waters of areas known to be impacted by acid inputs (Figure 18) (Davis 1980; Wright and Gjessing 1976, Cronan and Schofield 1979), and in effluent from lysimeters treated with acid solution (Dickson 1978, Abrahamsen et al. 1976). While aluminum ordinarily is leached from the upper soil horizon of podsol soils by carbonic acid, tannic and humic acids, and organic chelation, it is usually deposited in lower horizons. Under the influence of strong acids in precipitation, however, the aluminum may be mobilized in the upper (slightly acid) soil horizons and transported by saturated flow through the surface layers into lakes and streams (Cronan and Schofield 1979, Hall et al. 1980, Herrmann and Baron 1980). Elevated aluminum concentrations have been shown to occur during the spring melt of the snowpack, when large quantities of H ions are released into the saturated surface layers (Seip et al. 1980, Driscoll 1980).

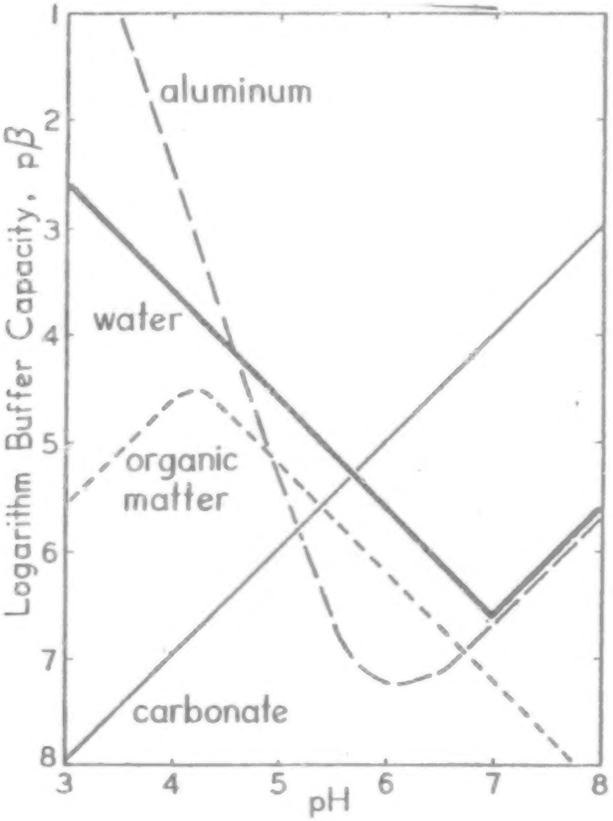


Figure 17. Logarithm buffer capacity diagram of dilute acidified waters (modified from Bisogni and Driscoll 1979).

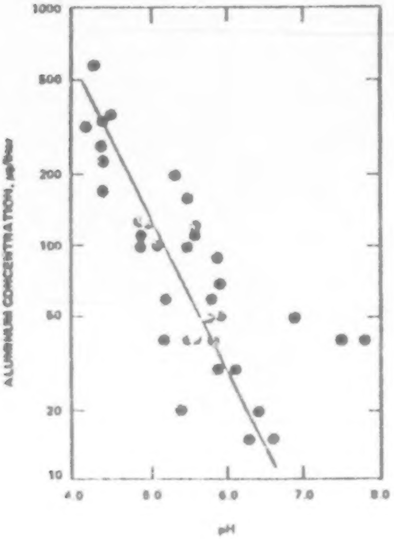


Figure 18. Relationship of observed stream concentrations of aluminum to the pH of surface water (Wright and Gjessing 1976).

The mechanism supplying Al to soil water, and therefore to shallow interflow water, is the decomposition of alumino-silicates and gibbsite. Norton (1976) and Reuss (1976) suggest the following model:

$Al_2Si_2O_5(OH)_4 + 6H^+ = 2Al^{3+} + 2H_4SiO_2 + H_2O$
$Al(OH)_3 + H^+ = Al(OH)_2^+ + H_2O$
$Al(OH)_2^+ + H^+ = Al(OH)^{2+} + H_2O$
$Al(OH)^{2+} + H^+ = Al^{3+} + H_2O$

These reactions are likely to occur in watersheds where there are no carbonates to consume H, and the above reactions become the primary buffering mechanism (Johnson 1979, Kramer 1976). The pH at which this buffering occurs is around 4.5-5.0, as indicated by the Al solubility diagram of Driscoll (1980) which shows $Al(OH)_3$ beginning to decline rapidly at pH 5, as Al begins to increase.

In aquatic systems, aluminum forms a variety of complexes with water and its constituents, including hydroxide, fluoride, silicate, organic matter and sulfate (Everhart and Freeman 1973, Driscoll 1980, Baker and Schofield 1980). According to Johannessen (1980), these aluminum complexes act as a buffer in the pH range 4.5-5.0, but above and below these levels, buffering cannot be ascribed to aluminum complexes. Henriksen (1980) shows that lakes with pH 4.6-4.8 have a higher pH than expected from a theoretical "titration" curve based on bicarbonate buffering, and that the extra buffering can be explained by aluminum.

In surface waters of the Adirondack Region of New York, Driscoll (1980) found aluminum-organic complexes as the predominant monomeric form (average = 44%), which increased linearly with total organic carbon content. Aluminum-fluoride complexes were the most abundant inorganic form (average 29% of the total monomeric Al), with concentration increasing with decreasing pH, although their formation was generally limited by fluoride concentration.

A decrease in the pH of natural water columns can cause an increase in the availability of some metals. Schindler (1980) found substantial increases in lake water concentration of Al, Mn, Zn, and Fe, at pH 6 and 5, in acidified limnocoralls in the Experimental Lake Area. Zinc concentrations at pH 5 exceed levels found to be toxic to fish. Also, radionuclides of Fe, Co, Mn, and Zn were found to be more soluble in acidified systems, where Hg and V radionuclides were less soluble. Elevated manganese, zinc, and cadmium concentrations have been measured in acidified streams and lakes in Scandinavia (Wright and Gjessing 1976, Dickson 1975, Almer et al. 1978).

Acidic deposition is known to affect steel, copper, galvanized sheet and other metals, stone, paints, and plastics, both through dry and wet deposition (see Materials Subgroup report). Exposure to atmospheric sulfur compounds can cause scaling and loss of surface cohesion in limestone and sandstone. Thus the effects for aquatic resources of acidic rainfall on construction materials such as roofing (see Materials Subgroup report), can be of importance to water quality. Similarly, materials such as in solid waste and mine tailing disposal sites may be influenced more by acidic deposition and runoff than by relatively neutral precipitation (Andrews 1975, and Poldoski and Glass 1975). The magnitude of these effects is not known at this time.

THE EFFECT OF NATURAL ORGANIC ACIDS ON THE pH OF SOFT WATERS

Acidity Contribution

Certain lakes and streams can have low pH values as a result of natural processes. A major portion of the organic acids in natural waters is organic acids such as amino acids, produced by living organisms, and humic and fulvic acids, produced by the microbial degradation of plant and animal organic matter. The concentration of amino acids in water is usually in the low parts-per-billion range, and, since their acid dissociation constants are low, they do not contribute significantly to the acidity of the water. The concentration of humic and fulvic acids in water is usually much higher than that of the amino acids. Also, humics and fulvics have much higher acid dissociation constants, and can have a considerable influence on the pH of water. As an example, bogs or swamps containing high concentrations of humic material and low concentrations of major ions can have pH's between 3.8 and 4.2.

A dramatic example of the effect of humics on stream water acidity was recently reported by Ramberg (1981). A Swedish runoff brook fed mainly by groundwater had an average pH of 4.9. When drainage ditches were dug so that the groundwater no longer flowed through the upper organic layer of the forest soil before reaching the brook, the pH of the stream increased to a mean value of 5.8.

Buffering Capacity

Humic materials have recently been shown to have low buffering capacity even when present in high concentrations (Wilson 1979). The weak buffering capacity they do exhibit is between pH 4 and 5, the pH region in which the endpoint of alkalinity titrations occurs. In systems with low alkalinity, the presence of humics can lead to a significant overestimation of alkalinity when the usual acidimetric determination method is used (Wilson 1979). Whether or not humics interfere with the recently proposed "total fixed endpoint" alkalinity procedure is unknown (Jeffries and Zimmerman 1980). The relative contribution of organic matter to the buffer intensity in relation to other buffering substances is shown in Figure 17 (Driscoll 1980). These substances can influence the bioavailability of acid-loaded cations such as Al, Mn and Zn by acting as chelators, however.

Work is currently in progress on determining the acid dissociation constants of diverse aquatic humics from across Canada. Also, methods are being developed to quantify the carboxylic acid groups in these materials, since common analytical techniques such as color, ultraviolet absorbance, fluorescence and total organic carbon do not correlate well with each other or with the acidic properties of the materials. The ultimate goal of this research is to define what portion of the H ion in environmental samples is from the dissociation of weak acids and what portion is from the strong acids in precipitation.

CATION AND ANION BUDGETS

Calibrated lakes and watersheds, that is, natural catchments for which the input and output rates of substances can be measured, are an established research tool in environmental studies. For example, the development of strategies for the management of eutrophication of lakes by phosphorus control was based largely on mass balance studies and models (Vollenweider 1975, Dillon and Rigler 1975, Oglesby 1977a, 1977b, Reckhow 1979).

Common reasons for the use of this approach include:

(a) relative importance of the different inputs of a pollutant can be assessed and abatement planned accordingly;

(b) mass balances can be used with mathematical models to predict the chemical concentrations of the substance in the receiving body, either the stream draining the calibrated watershed, or the calibrated lake itself; and

(c) quantitative accounting of the flow of substances in the watershed or lake may provide information concerning the processes and mechanisms occurring there.

Element Budgets at Hubbard Brook, New Hampshire

Ionic balances of watersheds have been used as a means of quantifying the net basin reactions resulting from acidic deposition. Several studies have been underway since the early 1960s. The earliest study and the longest record (1963-present) is the work at Hubbard Brook, summarized by Likens et al. (1977, 1980).

The bulk ionic composition of precipitation at the Hubbard Brook ecosystem is characterized primarily by acids such as H_2SO_4, HNO_3 and HCl. In contrast, water leaving the system is characterized mainly by neutral salts, composed of Ca, Mg and Na balanced in solution by SO_4 and NO_3, and to a lesser extent by chloride and bicarbonate species. The chemical and biological reactions of hydrogen ion, nitrate, ammonium and sulfate are very important in driving displacement and weathering reactions, especially when considering the effects of acidic precipitation.

Observed trends and annual ion budgets for 11 years at Hubbard Brook demonstrate the influence of atmospheric inputs on surface water quality. Unusually high rates of H, NO_3, and SO_4 inputs were observed as early as 1964. The average annual weighted pH from 1964-1965 through 1973-1974 ranged between 4.03 and 4.21. The lowest value recorded for a storm at Hubbard Brook was pH 3.0 and the highest was 5.95. During the period 1969-1974 (the latter being the last year of the 1977 summary), no weekly precipitation exceeded a pH of 5.0. Concentrations for SO_4 and NH_4 vary from year to year, but show no statistically significant time-trends for the period. In contrast, annual weighted NO_3 concentrations were about 2.3-fold greater in 1974 than they were in 1955-1956 or in 1964-1965. The fluctuations in hydrogen ion deposition can be explained in large part by the fluctuation in total precipitation.

Figure 19 demonstrates that from 1964 to 1970 there was a general downward trend in the sulfate contribution to the total of measured anion equivalents (Likens et al. 1980). Since about 1970 the rate of decline has been less, or even reversed. The proportion of nitrate in the total has tended to increase throughout the period. The authors believe two conclusions can be drawn: (i) there has been an increasing importance of nitric acid in precipitation at Hubbard Brook; and (ii) the average annual change was somewhat smaller after 1970, apparently due to smaller annual increases in measured nitrate concentration in precipitation after 1970. The proportion of hydrogen ion to the total cations has increased throughout the period, but this is primarily a function of the decrease in total cation equivalents of which hydrogen ion is the major component.

The Hubbard Brook study site is an isolated headwater catchment; thus the influx of chemicals is limited to precipitation and dry deposition, and the outflow to drainage waters. Theoretically, differences between annual input and output for a given chemical indicate whether that constituent is being accumulated within the ecosystem; is being lost from the system; or is simply passing through the system. Likens et al. (1977), therefore, were able to estimate with reasonable accuracy the mean annual budgets for most of the major ions (Table 5). Over the long term, there is considerable variation; however, a net annual loss of calcium, magnesium, potassium, sodium, sulfate, aluminum, and dissolved silica has occurred along with a net annual gain of ammonium, hydrogen ion, and phosphate in these undisturbed, accreting watershed ecosystems.

Overall, during 1964-1974, there was an annual net loss of total dissolved inorganic substances from the experimental watersheds, amounting

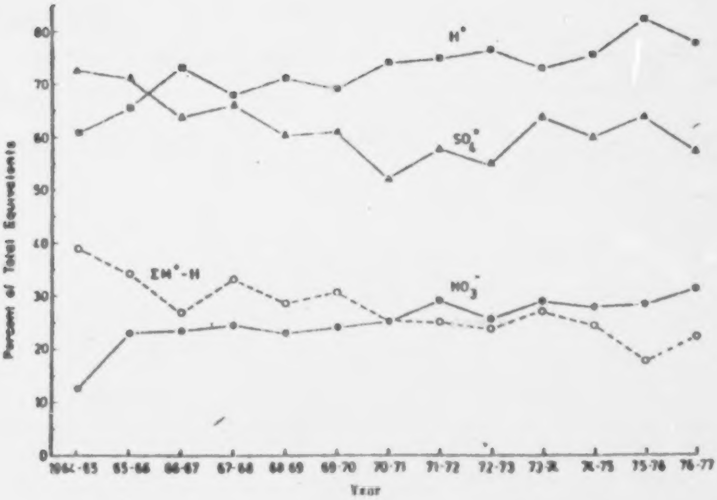


Figure 19. Percent of ionic composition of precipitation for the Hubbard Brook Experimental Forest during 1964 to 1977. ΣM+ is sum of all cations. (Likens et al. 1980).

Table 5. ANNUAL BUDGETS OF BULK PRECIPITATION INPUTS AND STREAM-WATER OUTPUTS OF DISSOLVED SUBSTANCES FOR UNDISTURBED WATERSHEDS OF THE HUBBARD BROOK EXPERIMENTAL FOREST (LIKENS et al. 1977).

Substance	1963 to 1964	1964 to 1965	1965 to 1966	1966 to 1967	1967 to 1968	1968 to 1969	1969 to 1970	1970 to 1971	1971 to 1972	1972 to 1973	1973 to 1974	Total 1963-1974 kg/ha	Annual mean kg/ha
CALCIUM													
Input	3.0	2.8	2.7	2.7	2.8	1.6	2.3	1.5	1.2	1.2	2.0	23.8	2.2
Output	12.8	6.3	11.5	12.3	14.2	13.8	16.7	13.9	12.4	15.6	21.7	151.2	13.7
Net	-9.8	-3.5	-8.8	-9.6	-11.4	-12.2	-14.4	-12.4	-11.2	-14.4	-19.7	-127.4	-11.5
MAGNESIUM													
Input	0.7	1.1	0.7	0.5	0.7	0.3	0.5	0.5	0.4	0.5	0.4	6.3	0.6
Output	2.5	1.8	2.9	3.1	3.7	3.3	3.5	3.1	2.8	3.3	4.6	34.6	3.1
Net	-1.8	-0.7	-2.2	-2.6	-3.0	-3.0	-3.0	-2.6	-2.4	-2.8	-4.2	-28.3	-2.5
ALUMINUM													
Input	*	*	*	*	*	*	*	*	*	*	*	*	*
Output	1.6°	1.2	1.7	1.9	2.1	2.2	2.2	1.8°	1.7°	2.3°	3.2°	21.9	2.0
Net	-1.6	-1.2	-1.7	-1.9	-2.1	-2.2	-2.2	-1.8	-1.7	-2.3	-3.2	-21.9	-2.0
AMMONIUM													
Input	2.6°	2.1	2.6	2.4	3.2	3.1	2.7	3.9	2.8	2.5	3.7	31.6	2.9
Output	0.27°	0.27	0.92	0.45	0.24	0.16	0.51	0.23	0.05	0.18	0.42	3.7	0.34
Net	2.3	1.3	1.7	2.0	3.0	2.9	2.2	3.7	2.7	2.3	3.3	27.9	2.6
HYDROGEN													
Input	0.85°	0.76	0.85	1.05	0.96	0.85	0.93	1.18	0.97	1.08	1.14	10.62	0.96
Output	0.08°	0.06°	0.05	0.07	0.06	0.09	0.09	0.14	0.13	0.16	0.20	1.13	0.10
Net	0.77	0 70	0.80	0.98	0.90	0.76	0.84	1.04	0.84	0.92	0.94	9.49	0.86
SULPHATE													
Input	33.7°	30.0	41.6	42.0	46.7	31.2	29.3	34.6	33.0	43.4	52.8	418.3	38.0
Output	42.7°	30.8	47.8	52.5	58.5	53.5	48.1	51.1	46.8	64.0	84.7	580.3	52.8
Net	-9.0	-0.8	-6.2	-10.5	-11.8	-22.1	-18.8	-16.5	-13.8	-20.6	-31.9	-162.0	-14.8
NITRATE													
Input	12.8**	6.7	17.4	19.9	22.3	15.3	14.9	21.6	21.4	26.3	30.9	209.5	19.0
Output	6.7**	5.6	6.5	6.6	12.7	12.2	29.6	24.9	18.7	19.2	34.8	177.5	16.1
Net	6.1	1.1	10.9	13.3	9.6	3.1	-14.7	-3.3	2.7	7.1	-3.9	32.0	2.9
BICARBONATE***													
Input	*	*	*	*	*	*	*	*	*	*	*	*	*
Output	6.2°	4.6°	6.2	9.4	9.6	7.0	6.0	7.1°	6.6°	9.0°	12.5°	84.2	7.7
Net	-6.2	-4.6	-6.2	-9.4	-9.6	-7.0	-6.0	-7.1	-6.6	-9.0	-12.5	-84.2	-7.7

* Not measured, but trace quantities. ° Calculated value based on weighted average concentration during years when chemical measurements were made and on amount of precipitation or streamflow during the specific year. ** Calculated from weighted concentration for 1964-1966 times precipitation for 1963-1964. Based on annual concentration of 0.50 mg/ℓ (Juang and Johnson, 1967). *** Watershed 4 only.

to 75.8 kg ha^{-1} yr^{-1}. The average net output of dissolved inorganic substances minus dissolved silica (1963-1974) was 37.4 kg ha^{-1} yr^{-1}. The smallest annual net load of dissolved inorganic substances (27.8 kg/ha, or 7.0 kg/ha for total material, minus dissolved silica) occurred during 1964-1965, the driest year of the study. The largest net losses of dissolved inorganic substances occurred during the wettest year, 1973-1974 (139.7 kg/ha, or 986 cationic eq/ha).

Likens et al. (1977) also note the complexity of the calculation of long-term cationic denudation in the Hubbard Brook ecosystem due to accumulations of living and dead biomass. The total amount of cations sequestered by this means is 72.2 meq m^{-2} yr^{-1}. They conclude that: (a) cations stored within the biomass must be included in calculations of contemporary weathering, and (b) the rate of storage is a consequence of the ecosystem's current state of forest succession, and so changes with time.

If this appraisal of the biological system at Hubbard Brook is correct, the flux of cationic nutrients being diverted into biomass accretion (72.2 meq m^{-2} yr^{-1}) must be added to that actually removed from the system, in the form of dissolved load (126.7 meq m^{-2} yr^{-1}) and particulate organic matter (1.0 meq m^{-2} yr^{-1}). Therefore, their best estimation of cationic denudation (net loss from ecosystem plus long-term storage within the system) at Hubbard Brook is about 200.0 meq m^{-2} yr^{-1}.

These long-term estimates of cationic denudation at Hubbard Brook allow estimation of the relative importance of external and internal sources of H ions. The external supply rate is 100.0 meq m^{-2} yr^{-1} and, by difference, the internal source becomes 100.0 meq m^{-2} yr^{-1}. This suggests that under prevailing biological and chemical conditions (perhaps altered by changes in atmospheric precipitation), external and internal generation of H ions play nearly equal roles in driving the weathering reactions.

Element Budgets in Canada

Input-output budgets (mass balances) for major ions are being measured at a number of locations in Canada described in Tables 6 and 7. In all cases, mass balance measurements have excluded possible contributions via subsurface flow, although the evidence available suggests that these contributions are negligible. Net exports of Ca, Mg, and K are shown in Table 7 for watersheds, along with input of H by precipitation. Output of HCO_3 and input-output data for SO_4, NH_4 and NO_3 are also included where reported. Nicolson (1977) reported only output of major ions from 12 watersheds in the Experimental Lakes Area, northwestern Ontario; however, input by precipitation to the nearby Rawson Lake watershed (Schindler et al. 1976) was used to calculate a net export for these 12 watersheds.

Several general trends are evident in Table 7. All watersheds studied have a net output of the major cations (Ca + Mg + Na + K). The net output of Ca and Mg dominates the budgets at all locations, particularly those in British Columbia where the watershed has some calcareous till. The study sites in British Columbia receive a large amount of precipitation (260-450 cm/yr), a factor that also may increase the export of cations.

TABLE 6. DESCRIPTION OF WATERSHEDS IN CANADA UTILIZED FOR MASS BALANCE STUDIES.

	Description of watershed				
Study location	A (km^2)	Annual ppt. (cm)	Forest, soil and bedrock geology	Study period	Reference
Carnation Creek, Vancouver Is.	10	300	Forest: hemlock, fir, cedar Soils: shallow, medium to coarse textured alluvial podzols; some areas of high organic content Bedrock: massive, metamorphic, primarily silicates of variable composition with some marble and igneous intrusions	2 yr.	Scrivener 1975
Jamieson Creek, Seymour Basin, Southwest B.C	2.99	450	Forest: fir, hemlock, cedar Soils: shallow, podzolic tills and colluvium (sometimes gleyed) Bedrock: massive, plutonic, horneblende-diorite	1 yr.	Zeman 1975
3 watersheds at Haney, Southwest B.C.	0.23-0.44	257	Forest: hemlock, cedar, fir Soils: generally deep, permeable podzolic tills and colluvium (sometimes gleyed) Bedrock: massive, plutonic, horneblende-diorite	2 yr.	Feller 1975, 1977
12 watersheds, Experimental Lakes Area, Western Ont.	0.35-12.5	est. 60-100	Forest: pine, spruce, birch, aspen Soils: shallow, podzolic basal tills; extensive bedrock exposure on hill crests; deep soils (10-15 m) in low areas	4 yr.	Nicolson 1977
Rawson Lake watershed, Experimental Lakes Area, Ont.	3.42	70-100	Bedrock: massive, plutonic, granodiorite	4 yr. published, 5 unpublished	Schindler *et al.* 1976
Clear Lake watershed, Haliburton, Ont.	1.25	126	Forest: maple, beech, oak, birch, balsam, hemlock Soils: shallow, podzolic basal tills with bedrock exposure on steeper slopes Bedrock: jointed, intruded, metamorphic, granite gneiss	1 yr.	Schindler & Nighswander 1970
Harp Lake watershed, Haliburton-Muskoka, Ont.	3.70	82 (99 is long-term mean)	Forest: maple, beech, birch, balsam, and hemlock Soils: generally shallow podzolic tills with some deeper sand deposits Bedrock: jointed, intruded, metamorphic, horneblende-gneiss and amphibolite with small occurrence of diorite	4 yr. unpublished, ongoing	

TABLE 7. NET EXPORT OF MAJOR IONS FOR CALIBRATED WATERSHEDS IN CANADA (FROM HARVEY *et al*. 1981).

Watershed	Net export (meq m^{-2} yr^{-1})									Input of H (meq m^{-2} yr^{-1})
	Ca	Mg	Na	K	ΣM	NH$_4$	NO$_3$	HCO$_3$	SO$_4$	
Carnation Creek, Vancouver Is.	269	61.2	118.5	5.8	454.5	-7.7	-4.3	270.0	131.4	1-3
Jamieson Creek, B.C.	171.6	54.4	53.9	4.3	284	-0.2	-2.2	48.7	4.9	-
Twelve watersheds, ELA, Western Ontario	36.6[a] 17.7[b]	24.0 16.4	18.0 11.1	3.4 0.5	82.0 45.7	-0.9	-0.8	-	38.8	est. 7-10
Rawson Lake watershed, Western Ontario	11.2	12.1	9.0	0.4	32.7	Total N reported			0.9	~7-10
Four subwatersheds, of Harp Lake; Muskoka-Haliburton, Ontario	52.7	33.0	6.6	2.3	94.6	-30.2	-32.3	31.7	43.9	67

[a] Gross output.

[b] Estimated net output using input in precipitation from Rawson Lake watershed studies.

The net output of cations from the ELA and Rawson Lake watersheds on the Canadian Shield is only 30-40% of that from the Harp Lake watersheds, which are also on the Shield but on the more heavily acidified central Ontario section. The H input is 5-10 times lower. In 11 cases, there is a net accumulation of NH_4 and NO_3 in the watersheds. More sulfate is removed than is supplied at all watersheds, although at Rawson Lake and Jamieson Creek, the SO_4 input and output are probably within experimental error of being balanced. However, the actual amount of SO_4 supplied may be underestimated due to canopy effects and possible gaseous deposition. The greatest net output of SO_4 was measured at Carnation Creek (Scrivener 1975) and Harp Lake, although at the latter there was a substantial input of SO_4 in precipitation (≈70 meq m^{-2} yr^{-1}) (Scheider et al. 1979a).

The mechanism for cation export is apparent in some cases. At Carnation Creek, the output of HCO_3 is substantial, suggesting that carbonic acid is the principal weathering agent responsible for cation export. At the Experimental Lakes Area in northwestern Ontario (including the Rawson Lake studies), the release of cations probably is a result of carbonic acid weathering, although the loading of 7-10 meq H m^{-2} yr^{-1} in precipitation may account for 20% of the net cation export. On the other hand, in southern Ontario, 50% or more of the cation yield probably results from input of H in strong acid form. Although the evidence is circumstantial, it appears likely that the increased H input of southern Ontario has resulted in a two- to four-fold increase in net output of cations.

Regional Responses in Lake Chemistry

A decade of results in Scandinavia indicate that as lakes are subjected to acidic deposition, cations are mobilized, and some of the bicarbonate ions are replaced by sulfate; thus, the normal relationship between the dominant cations, calcium and magnesium, and alkalinity appears to be altered. Although these lakes are not necessarily acidic, the alkalinity will be less than predicted, i.e., when calcium plus magnesium are summed.

The report by Harvey et al. (1981) gives a similar evaluation of lake data for North America. Their description is as follows:

> "Comparable data for lakes on the Canadian Shield are shown in [Figure 20]. Lakes that can be considered unaffected by acidic deposition include those in the Northwest Territories, probably Labrador and Newfoundland, and northern Manitoba and Saskatchewan. These lakes have close to a 1:1 relationship between [Ca^{2+} + Mg^{2+}] and [HCO_3], as do several lakes in calcareous pockets in the Killarney area of Ontario. [Ca^{2+} + Mg^{2+}] may be overestimated for several of the Newfoundland and Labrador lakes because the concentrations are not corrected for sea salt contributions. Many of the other lakes, however, have a HCO_3 deficiency relative to Ca^{2+} plus Mg^{2+}; most of the Killarney lakes, including all the LaCloche Mountain lakes and many of the Whitefish Reservation lakes, almost all of the lakes within a 100-km radius of Sudbury, Ontario, and all of the Muskoka-Haliburton lakes and Nova Scotia-New Brunswick lakes (although the latter data were also not corrected for sea salt contribu-

tions) have HCO_3^- deficiencies. The distance below the line in [Figure 20] may be an indication of the extent of acidification; lakes found below . . . zero alkalinity are considered to be acidified.

"If the other major source of Ca^{2+} and Mg^{2+} in lake water is weathering by strong acids in precipitation, and if most of this acid is associated with sulfate, then there should be a good relationship between [SO_4^{2-}] and [Ca^{2+} + Mg^{2+} - HCO_3] on an equivalent bases. This relationship provides an estimate of the Ca^{2+} and Mg^{2+} not derived from carbonic acid weathering. Data for Canadian Shield lakes [show] the agreement between [SO_4^{2-}] and [Ca^{2+} + Mg^{2+} - HCO_3^-] for most lakes is very good, although it can be argued that this may be expected, based on the principle of charge balance, and implies no cause-effect relationship. All of the lakes in Nova Scotia and New Brunswick [have excess Ca and Mg] suggesting that Ca^{2+} and Mg^{2+} may be supplied in part by sea salt. The Whitefish Reservation lakes [are outliers] but this may result from analytical error as the total charge balance for the Whitefish Reservation data is not good, a problem that does not exist with the other data sets.

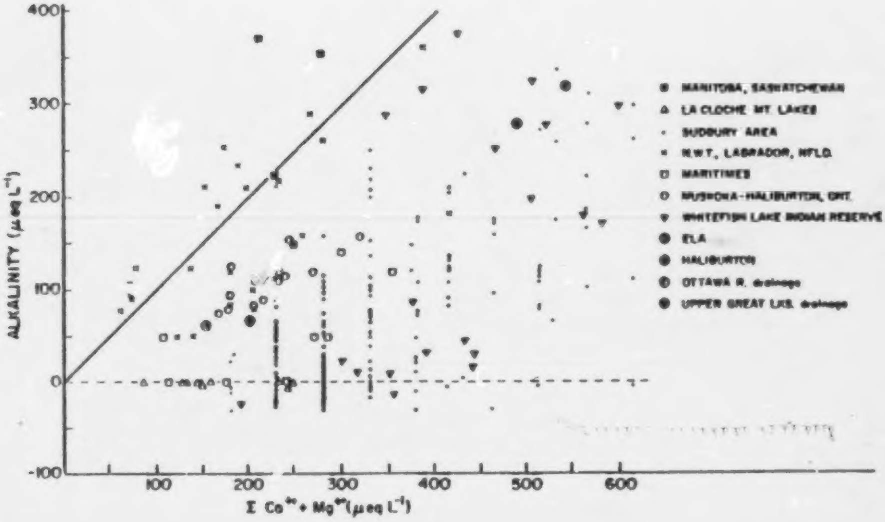


Figure 20. Summary of alkalinity data from several Canadian lake studies, including sites inside and outside acidic deposition areas (Harvey et al. 1981).

> "The fact that most lakes or groups of lakes have reasonably close correspondence between $[Ca^{2+} + Mg^{2+} - HCO_3]$ and $[SO_4^{2}]$ supports the hypothesis that the Ca^{2+} and Mg^{2+} content of lakes is not derived from carbonic acid weathering but is related to the input of sulfate. Because the other major strong acid anion, NO_3, is a nutrient in lakes and streams (i.e., is non-conservative), it is not possible to incorporate it into a more complete relationship."

Effects of Forest Manipulation or Other Land Use on Watershed Outputs

Land use practices within watersheds have been suggested as an influence on the budgets (Rosenquist et al. 1980, Likens et al. 1978, Henderson et al. 1980). Henderson et al. (1980) have summarized results from watersheds at Hubbard Brook, Fernow, and Coweeta that were experimentally manipulated through a series of forest cutting practices. The work was designed to estimate changes in streamflow of cations, particularly potential effects on H concentrations. At Hubbard Brook, following felling of all vegetation and herbicide treatments for three successive years, an increase of 245.9 kg/ha of nitrogen discharges into stream flow was observed. Increased acidity from biomass decomposition amounted to 69.9 x 10^3 eq H/ha. This additional acidity is presumed to have been a major contributor to the loss of cations from the soil, shown in Table 8.

Strip cutting of one-third of the vegetation at a second Hubbard Brook watershed showed significantly less impact on soil leaching rates. Organic matter decomposition was about 5% of that of the total vegetation removal (500 kg/ha versus 10,500 kg/ha). Subsequently, H production also was less, as was resultant cation leaching.

Commercial clear-cutting at the Fernow watershed generated fewer H equivalents. This result may have been due to removal of only "economic biomass", which reduced overall decomposition rates and resultant H formation. The Coweeta clear-cut and cable logging experiments resulted

TABLE 8. SUMMARY OF TOTAL CATION RELEASE, HYDROGEN PRODUCTION AND THE CATION RELEASE RATIO FOR THREE MANIPULATED-WATERSHED STUDIES.

	H produced (eq/ha)	Total cation release (eq/ha)	Cation release ratio (eq/eq H)
Hubbard Brook, New Hampshire			
Deforested	69,960	6,850	0.10
Strip-cut	8,400	390	0.05
Fernow, West Virginia			
Clear-cut	960	170	0.18
Fertilization	55,710	2,420	0.04
Coweeta, North Carolina			
Clear-cut and cable-logged	360	50	0.14

From: Henderson et al. 1980

in even less production of H ions. When the Fernow watershed was fertilized with 260 kg/ha of urea, a ten-fold stripping of calcium ions occurred, plus a 6-fold increase in magnesium, a 50% increase in potassium leaching, and a 3.6-fold increase in sodium ion denudation.

The high, median and low cation release ratios from Table 8 were used to calculate leaching increase potentials for three precipitation acidity scenarios (Table 9). Additional H inputs of 750, 3,990, and 14,250 eq/ha would be experienced for 150 cm of precipitation at pH 4.0, 3.5, and 3.0, respectively. At the more acidic pH values, aluminum leaching (and, therefore, buffering of effects on the other cations) would be expected to increase substantially.

The possibility of land use changes causing acidification of surface waters, rather than atmospheric inputs of acid, has been explored in great detail in two recent studies in Norway. Seip (1980) concluded that while land use changes probably have contributed to the acidification process in some areas, "there is no reason to doubt that the increase in the deposition of acidifying components has played an important role in the acidification of freshwater." Drabløs et al. (1980) also reviewed land use changes in relation to declining fish populations in lakes and could find no relationship between the two. In fact, the greatest number of lakes from which fish populations have been lost occurred in areas of no farming activity. Thus, while it is well documented that land use changes affect the quality of runoff, including pH, the large scale acidification of lakes in Scandinavia has not been due to land use changes.

TABLE 9

POTENTIAL INCREASE IN CATION LEACHING
EXPECTED UNDER THREE PRECIPITATION ACIDITY REGIMES

pH	Additional H (eq/ha)	Cation leaching potential (eq/ha) Low	High	Median
4.0	750	30	135	75
3.5	3,990	160	720	400
3.0	14,250	570	2,565	1,425

From: Henderson, G.S., et al. 1980.

ALTERATIONS OF SURFACE WATER QUALITY

Soil Mediation of Atmospheric Inputs

Geochemical processes in the surface layers of watersheds (vegetation layers as well as the upper soils) provide important integrative processes by which altered precipitation chemistry can cause the chemical changes noted in the previous sections. The available data can be viewed as relevant to four types of questions: soil mediation of the inputs; the present status of aquatic systems; evidence as to time-trends in water quality measures; and the patterns of seasonal or episodic variation in water quality.

In assessing the capacity of watersheds to take up acidic substances, the vegetation, the soil, and the bedrock must each be considered as potentially modifying the inputs and releasing a portion of them to surface runoff and ground-water. Three levels of sensitivity for soils (and, therefore, water) have been embraced by McFee (1980) and by Wang and Coote (1980) using base exchange relationships. A map of the sensitivity for soils to allow surface water alteration in the eastern United States has been produced at the Oak Ridge National Laboratory (Olson et al. 1981). Bedrock sensitivity (obtained from Hendrey et al. 1980), exchangeable base content, and an allowance for SO_4 adsorption, widely recognized for its role in buffering the acidity in precipitation (Johnson 1980, Johnson et al. 1980), were used in combination to prepare the map. Bedrock sensitivity was based on the occurrence of type 1 (low to no buffering capacity) and type 2 (medium to low buffering capacity) bedrock as defined by Norton (1980) and mapped by Hendrey et al. 1980. Those counties having 50% or more of type 1 bedrock were assigned high sensitivity. Approximately 20% of the counties in the eastern U.S. can be recognized as potentially sensitive to water quality alteration using these criteria. Canadian studies show an even larger proportion of eastern Canada is similarly sensitive. (For additional detail on soils and sensitivity mapping, see the Terrestrial Effects report in this series).

Present Status of Sensitive Aquatic Systems

Current data on pH, alkalinity, sulfate, and other chemical variables are available for a wide variety of climatic, geological, and biological conditions in eastern North America. These data give an idea of the current status of aquatic systems but do not necessarily indicate how or when that status was achieved or whether it is currently changing. Some insight into these questions is given by comparisons of water quality data from areas with quite different rates of acidic deposition. The comparisons are valid to the extent that geological conditions are comparable.

This approach is illustrated in Figure 21, where the mean and range of sulfate concentrations in lakes and streams from the ELA (Experimental Lakes Area, Kenora, Northwestern Ontario) to Labrador are plotted. The pattern of SO_4 concentrations in these surface waters bears a strong

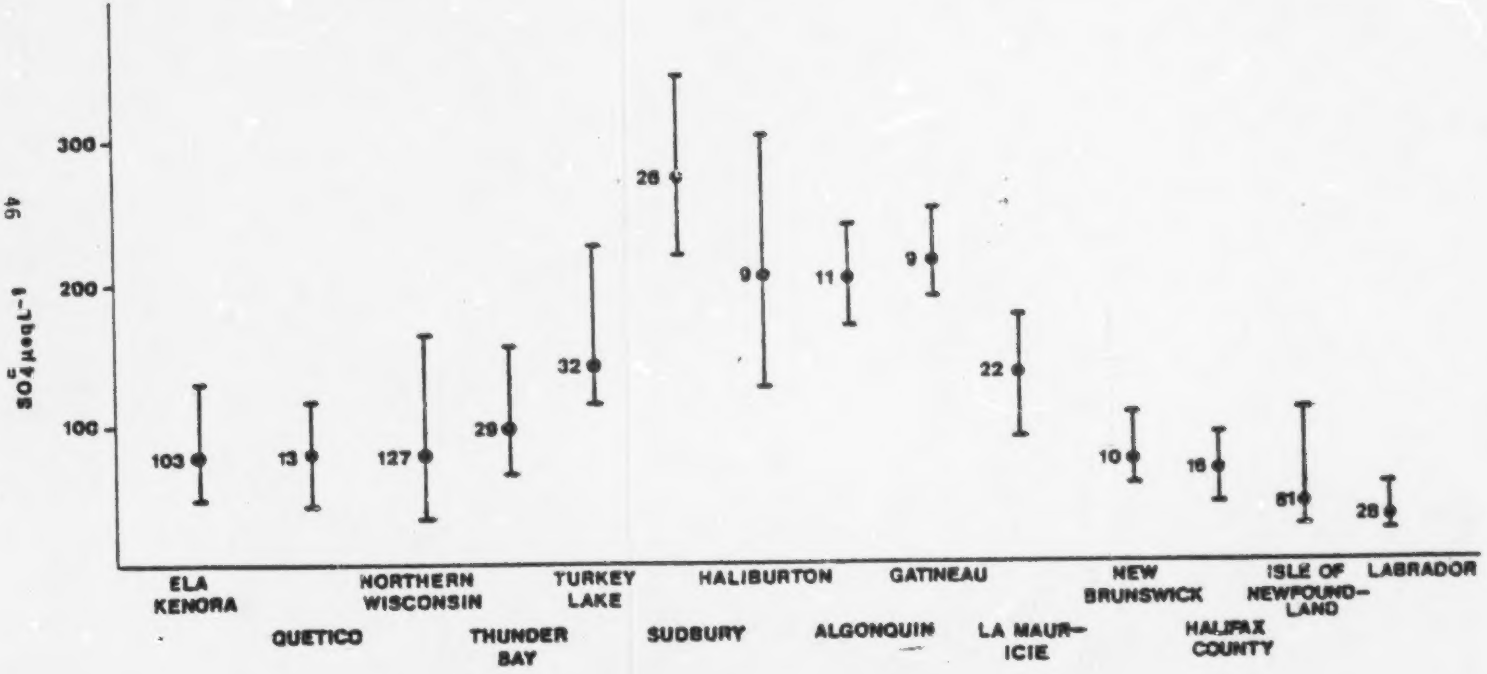


Figure 21. Mean and range of SO_4 or, near the coast, excess SO_4, in lakes and streams of eastern Canada. Sampling dates range from 1973 to 1981. See text for data sources.

resemblance to the pattern of wet deposition of SO_4 shown in Figure 6, from low levels at ELA, Quetico, and northern Wisconsin, rising in the neighborhood of Lake Superior (Thunder Bay and Turkey Lake), reaching a maximum in the lakes near Sudbury, but decreasing only slightly in the lakes east of Sudbury as far as La Mauricie in Quebec. The concentrations in Atlantic Canada are lower, with the lowest of all seen in the Labrador lakes, the most remote from SO_2 source areas.

This cross-section of the excess sulfate in the surface waters, when considered in conjunction with the measured wet deposition of sulfate, provides strong evidence that the atmospheric deposition from long range transport accounts for the elevated sulfate levels of the surface waters. Precise comparisons with the deposition values shown in Table 3 should not be expected, as variations due to dry deposition and concentrations of sulfate by evapotranspiration, and yearly variations influence the deposition measurements.

The data sources for Figure 21 are as follows:

ELA: Beamish, R. J., et al. 1976.

Quetico: Quetico-Lac Mille Lakes Fisheries Assessment Unit Lakes, Quetico Provincial Park, January 1981 (G. Beggs, Ontario Ministry of Natural Resources, personal communication).

Northern Wisconsin: Northern Wisconsin 1979 Fall Lake Survey (G. Glass, U.S. Environmental Protection Agency, Duluth, personal communication).

Turkey Lake: Lakes and streams in the Turkey Lake and Robertson Lake area, north of Sault Ste. Marie, Ontario, July 1979 (Environment Canada, National Water Research Institute, F. C. Elder, personal communication).

Sudbury: Sudbury District Lake Trout Lakes. Two were sampled in October 1979, twenty-four in January 1980 (G. Beggs, Ontario Ministry of Natural Resources, personal communcation).

Haliburton: Haliburton Highlands Fisheries Assessment Lakes, January 1981 (G. Beggs, Ontario Ministry of Natural Resources, personal communication).

Algonquin: Algonquin Fisheries Assessment Lakes, Algonquin Provincial Park, means of midlake composite samples 1979 (G. Beggs, Ontario Ministry of Natural Resources, personal communication).

Gatineau: Gatineau Park, Quebec, near Ottawa, Ontario, NAQUADAT 1973.

La Mauricie: Parc National de la Mauricie, July 1980 (Environment Canada, Quebec Region, R. Lemieux, personal communcation).

New Brunswick: Peterson, R. H. 1980.

Halifax: Lakes and rivers near Halifax, Nova Scotia, April 1980 (Environment Canada, Water Quality Branch, Atlantic Region, T. Clair, personal communication).

Isle of Newfoundland: Newfoundland Headwater lakes, November 1980 (Environment Canada, Water Quality Branch, Atlantic Region, T. Clair, personal communication).

Labrador: Clair, T. 1981.

A number of other studies have documented the present status of surface water resources in Canada, and can be summarized as follows:

Saskatchewan. Total alkalinity, calcium, magnesium, and pH of some 300 lakes in Saskatchewan's Shield and fringe Shield regions were analyzed to assess the sensitivity of these lakes to potential acidic deposition (Liaw and Alton 1981). Concentrations of alkalinity in these lakes varied from 10 to 1,740 µeq/ℓ as $CaCO_3$. Forty-four percent of the lakes surveyed had alkalinities of 200 µeq/ℓ or less, while 27% had between 200 and 400 µeq/ℓ. These two groups of lakes are considered to be highly or moderately sensitive to acidification.

Measurements of pH, ranging from 5.56 to 8.2, indicate that at present Saskatchewan's Shield lakes are not very acidic; lakes with pH values between 6.5 and 7.5 accounted for nearly 80% of all lakes investigated. Concentrations of calcium ranged from 0.33 to 31.60 mg/ℓ. About 54% of the lakes surveyed had calcium of 4 mg/ℓ or less, while 25% had between 4 and 8 mg/ℓ. Concentrations of magnesium varied from 0 to 10.7 mg/ℓ. Approximately 65% of the lakes measured had magnesium of 2 mg/ℓ or less, whereas 32% had between 2 and 3 mg/ℓ. Concentrations of calcium alone or together with magnesium were highly correlated to alkalinity.

The authors attempt to predict the anticipated rate of acidification (to pH 5.5), given the mean depth and alkalinity of the lake, and an assumed sulfur deposition rate of 0.4 g m^{-2} yr^{-1}. They suggest that in the event of acidic deposition, shallow and poorly buffered Shield lakes in northern Saskatchewan may be acidified in a matter of a few decades.

Ontario. About 6% of 1,527 lakes recently surveyed in Ontario were classified as acidified. These lakes were found to have an alkalinity equal to, or less than 0 microequivalents per litre (µeq/ℓ). An additional 12% (187 lakes) were classified as extremely sensitive, and a further 43% (482 lakes) were considered moderately sensitive (Table 10). Based on lake alkalinity data, it is reasonable to expect that up to 30% of the lakes in the important tourist areas of Muskoka-Haliburton will be acidified by present acid loadings, although the time scale cannot yet be defined. Data for the Manitoulin and Sudbury Districts must be interpreted with some caution since those areas were subjected to local problems related to smelting operations in Sudbury. Scheider et al. (1981) and Chan et al. (1980) indicate that long-range transport of acid to the area is substantial, but its influence relative to the historic local problems, with respect to acidifying lakes, cannot be determined.

Quebec. Vast areas of the Province of Quebec are composed of noncalcareous lithology, and glacial modifications have not provided calcar-

TABLE 10. SUMMARY OF THE PERCENTAGE OF LAKES IN EACH ALKALINITY CLASS BY COUNTY OR DISTRICT AND FOR ONTARIO.

County or District	Percentage of Total No. of Lakes and Streams in each Alkalinity Class: Acidified (≤ 0 μeq/ℓ)	Extreme Sensitivity (0-40 μeq/ℓ)	Moderate Sensitivity (40-199 μeq/ℓ)	Low Sensitivity (200-499 μeq/ℓ)	Not Sensitive (≥ 500 μeq/ℓ)	Total Number of Lakes
Algoma Dist.	5	11	30	28	26	163
Bruce Co.					100	7
Cochrane Dist.		7		11	82	27
Durham Co.					100	1
Frontenac Co.				6	94	64
Grey Co.					100	3
Haliburton Co.		21	40	24	15	110
Hastings Co.			21	11	68	63
Huron Co.					100	1
Kenora Dist.			14	25	61	88
Lanark Co.					100	15
Leeds Co.					100	24
Lennox & Addington Co.			36	12	52	25
Manitoulin Dist.	50	31	3	3	13	32
Middlesex Co.					100	1
Muskoka Dist.	1	30	61	2	6	115
Nippissing Dist.		9	75	13	3	75
Northumberland Co.					100	1
Ontario Co.					100	5
Parry Sound Dist.	5	20	64	10	1	107
Peel Co.					100	1
Peterborough Co.		4	16	6	74	49
Prince Edward Co.					100	3
Rainy River Dist.		3	64	19	14	99
Renfrew Co.			8	32	60	50
Simcoe Co.					100	7
Stormont Co.					100	1
Sudbury Dist.	23	29	24	11	13	208
Thunder Bay Dist.	1	2	25	27	45	136
Timiskaming Dist.	13		7	27	53	30
Victoria Co.					100	11
York Co.					100	2
Province %	5	12	32	16	35	100%
(No. of Lakes)	(81)	(186)	(487)	(241)	(530)	1,524

From: Ontario Ministry of Environment, 1981.

eous tills to modify the local soil structures. Only in the marine sediments of the St. Lawrence Valley and calcareous lithology of the Gaspe region is significant buffering material found.

It is estimated that the Province contains greater than one million lakes, the vast majority of which have not been surveyed. Present surveys have been limited to the southern, more accessible areas and are therefore likely biased towards the more buffered waters. While it is not possible to assess the degree of this bias, examination of the buffering capacity of the surface waters of the surveyed area gives an indication of sensitivity of waters of Quebec to acidification.

Figure 22 is a distribution of Calcite Saturation Index (CSI, Kramer 1976) of 297 lakes surveyed between 1976 and 1980. The CSI incorporates both alkalinity and hydrogen ion concentration into a logarithmic index of sensitivity to acidification. Insensitive or calcium saturated waters have a negative CSI, while waters having positive values greater than 2.5 to 3 are considered sensitive and values greater than 4 are highly sensitive. Figure 22 shows the distribution of CSI of surveyed lakes by hydrographic region of Quebec with more detailed surveys of the Laurentide and La Mauricie Parks. It is evident that nearly all waters other than the St. Lawrence Valley and the Gaspe Regions (Regions 01, 02 and 03) have CSI greater than 2.5 and are, as a result, sensitive to acidification. Surveys of the lakes of Laurentide and La Mauricie Parks appear to indicate a greater sensitivity than do the surrounding regions. This may be an actual indication of local differences in terrain geochemistry, but is believed to result from over-estimation of alkalinity in the older measurements. The actual sensitivity may therefore be even greater than indicated by the older surveys.

An earlier analysis of the same data base, but including only 215 lakes sampled between 1971 and 1977 (Legendre et al. 1980), has provided a summary of the lake status in terms of the sulfate/bicarbonate ratios. This ratio is an indication of the degree to which sulfate from atmospheric deposition has replaced bicarbonate in the natural water resulting from weathering. The summary shown in Table 11 has classified lakes into four values of the SO_4/HCO_3 ratio:

1. $R < 0.6$
2. $0.6 < R < 1.2$
3. $1.2 < R < 1.8$
4. $R > 1.8$

The lake summaries of Table 11 are shown by the same hydrographic regions as shown in Figure 22. It can be seen that Regions 01, 02, and 03 have the majority of lakes in category 1, i.e., HCO_3 dominates the SO_4/HCO_3 ratio, while Regions 04, 05, 06 and 07 have large portions of the lakes where SO_4 equals or exceeds the HCO_3. In these cases much of the original HCO_3 buffering has already been neutralized by the acidic sulphate deposition.

Labrador. As part of the Canadian Shield, Labrador is composed largely of granite with basic rock instrusions found mostly in the center of the region. It is covered by very thin topsoil and contains large

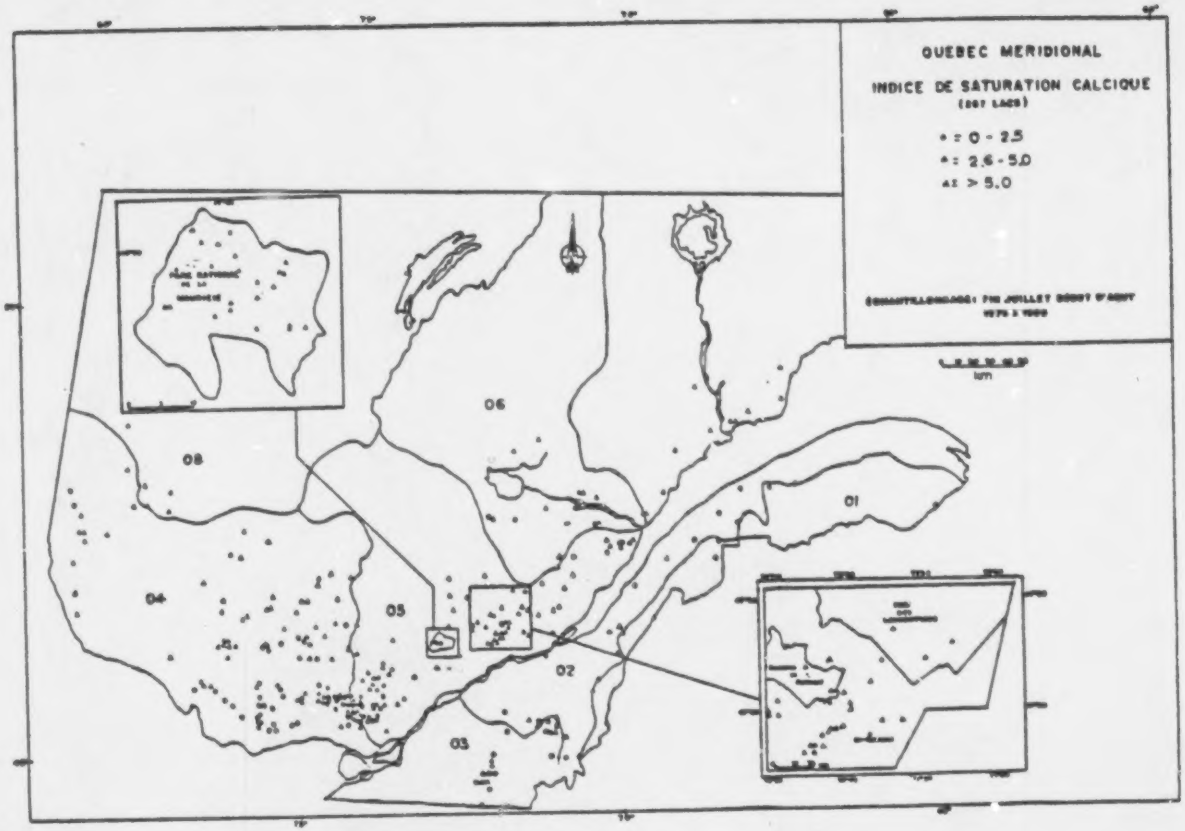

QUEBEC MERIDIONAL
INDICE DE SATURATION CALCIQUE
(297 LACS)
● : 0 - 2.5
▲ : 2.6 - 5.0
▲ : > 5.0
km
01
02
03
04
05
06
08

Figure 22. Calcite Saturation Indices for 297 lakes in central Quebec, 1976 and 1980. (Environment Canada 1981).

TABLE 11

SOME STATISTICS ON THE RATIO SO_4/HCO_3

	LAKES NORTH OF THE ST. LAWRENCE RIVER WEST → EAST HYDROGRAPHIC REGION							
Classes of Lakes	04		05		06		07	
	N	%	N	%	N	%	N	%
1	24	21.4	5	8.6	3	50.0	9	64.3
2	41	36.6	15	25.9	1	16.7	3	21.4
3	19	17.0	14	24.1	1	16.7	2	14.3
4	28	25.0	24	41.4	1	16.6	0	
TOTAL	112	100.0	58	100.0	6	100.0	14	100.0

	LAKES SOUTH OF THE ST. LAWRENCE RIVER WEST → EAST HYDROGRAPHIC REGION					
Classes of Lakes	03		02		01	
	N	%	N	%	N	%
1	21	95.4	13	76.5	5	100.0
2	1	4.6	3	17.6		
3	-	-	0			
4	-	-	1	5.9		
TOTAL	22	100.0	17	100.0	5	100.0

numbers of sphagnum bogs. Major ion chemistry data has been gathered from 400 sites from 1978 to 1980, which shows alkalinity values rarely higher than 150 μeq/ℓ except on anorthosite and gabbro intrusions (Clair 1981). Despite such high sensitivity, pH values are high with an average value near 6.4, suggesting that until now, acidic deposition has not changed the surface water quality of Labrador.

Atlantic Provinces. Except for northern New Brunswick and all of Prince Edward Island, most watersheds in this region provide little buffering capacity against acidic deposition (Figures 23 and 24). Much of the bedrock is granitic, overlain by thin podzol soils. Alkalinity values for 63 lakes located in eastern and southwestern Nova Scotia were all lower than 50 μeq/ℓ with summer pH values at certain weirs decreasing to a minimum of 4.5 (Water Quality Branch 1981). Use of Henriksen's (1979) model on 16 Nova Scotia lakes suggests that acidification of 40 to 50 μeq/ℓ has occurred over the past two decades, consistent with measured pH declines, (Thompson et al. 1980, Wiltshire and Machell 1981).

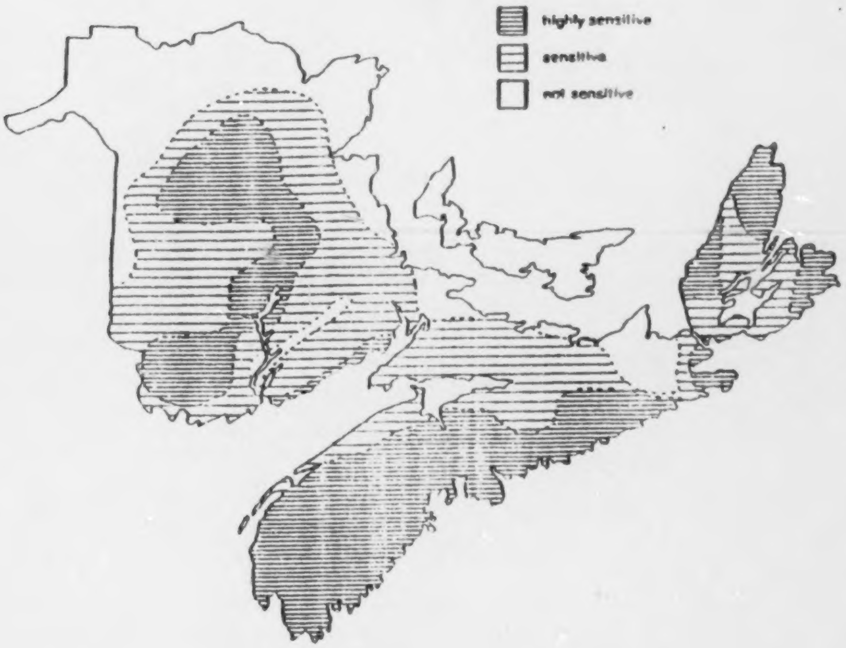


Figure 23. Sensitivity to acidification of surface waters in the Maritime Provinces (modified from Clair et al. 1979).

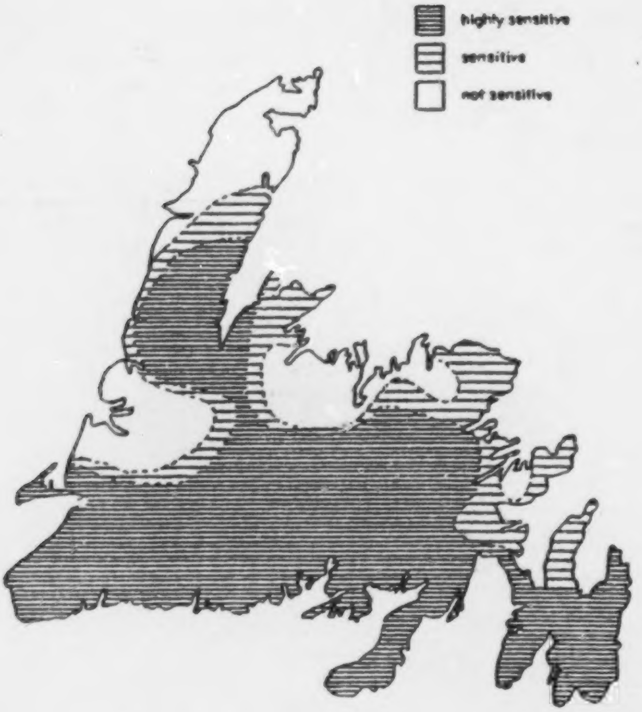


Figure 24. Sensitivity to acidification of surface waters in insular Newfoundland (modified from Clair et al. 1979).

Minnesota, Wisconsin and Michigan. Northern areas of Minnesota, Wisconsin, and Michigan are potentially susceptible to acidic deposition (Galloway and Cowling 1978) because coarse-textured soils there are very low in calcium carbonate, and are underlain by acidic igneous and metamorphic bedrocks and poorly buffered sandstone. The region's rich resources and related industries, including recreation, forestry, farming, and mining, would be vulnerable to disruption if acidic inputs reached levels presently being experienced in other areas of the United States. (See studies by Ulrich and Khanna, 1980, for effects on forests, and Andrews, 1975, or Poldoski and Glass, 1975, for pH effects on mine tailings.)

Available estimates indicate that Minnesota has from 15,000 to 22,000 lakes, covering 4,000 square miles. Half the lakes in the Boundary Waters Canoe Area Wilderness (BWCAW) are susceptible to acidification, due to low buffering capacity associated with alkalinities below 200 ueq/ℓ. Wisconsin has some 11,000 lakes more than 20 acres in size, and 2,600 lakes have a pH at or below 6.0 with little or no alkalinity (Glass 1980). Michigan has more than 10,000 lakes over 10 acres that are susceptible to acidification. Of some 8,000 lakes and ponds in the western half of the upper peninsula of Michigan, more than 50 percent have an alkalinity in the range of 10 ppm, indicating that they are potentially susceptible to acidic inputs.

Wisconsin has 2,250 trout streams, totaling 8,690 miles; stream data for the other two states were not available at the time of writing, but are geologically similar.

U.S. Surface Waters. The distribution of alkalinity in surface waters of various regions in the U.S. is summarized in Table 12 (from TIE 1981). All of the lakes and streams are in defined sensitive regions with low soil cation exchange capacity, non-buffering bedrock types and low sulfate adsorption (see terrestrial effects section). In general, the data show lowest alkalinity in eastern regions receiving the greatest acidic deposition; 38-81% of the lakes and streams are moderately sensitive to "acidified", with alkalinities ranging from less than 0 to 200 µeq/ℓ. Thirteen to 48% of Midwestern lakes and streams are in the same categories. In general, lakes appear to show lower alkalinity than streams for the same geology and deposition loading. In addition Crisman and Brezonik (1980) report that nine out of eleven lakes sampled in northern Florida were acidified (alkalinity ≤ 0).

Time-Trends in Surface Water Alterations

Questions of past and potential future changes in surface water acidification are best answered by detailed analysis of available long-term data. Such studies also can give an indication of other anthropogenic effects if accelerated acidification (over and above any natural acidification) is evident. Care must be taken in any historical studies, however, to account for differences between older methods of measurement and current methods. Precautions have been taken in the following analyses to correct for methodological differences, but these considerations must be remembered when making comparisons.

Time-trends in Nova Scotia, Newfoundland, and New Brunswick. Data from the mid-1950s for six rivers in Nova Scotia and one river in Newfoundland are compared with data for 1973 in Table 13. The results show decreases in pH and concurrent increases in excess SO_4 loads. The SO_4 being carried by these rivers is believed to have only two sources: long-distance transport of air pollutants and sea salt. Atmospheric deposition of sulfate ions at two monitoring stations in Newfoundland was compared with the sulfate ions carried by the local rivers. The result was a general correlation between sulfate ion load in the rivers and the amounts from precipitation. Also shown was a geographic pattern of decreasing sulfate loadings to the east and north, which was consistent with an assumption of long-distance transport of pollutants from urban centers.

Rivers in both Nova Scotia and Newfoundland show similar trends in pH and excess SO_4 loads over the period 1965 to 1980, as seen in Figure 25. Data for the Nova Scotia rivers since 1973 are sparse (four or fewer samples per year) so excess SO_4 loads cannot be calculated, but median pHs are shown. The lowest pHs and highest excess SO_4 loads were seen in 1973. The similarity in trends for rivers far apart in two different Provinces is good evidence that the changes are due to large-scale atmospheric loading changes, that is, to long-range transport of air pollutants. The figure also shows that when excess SO_4 loads are reduced, the pH of the rivers recovers promptly. However, even the reduced loads since 1973 are

TABLE 12. PERCENTAGE OF LAKES AND STREAMS IN VARIOUS SENSITIVITY CLASSES, CLASSIFIED FOR SIX LOCATIONS IN THE EASTERN U.S. AND FOUR IN THE UPPER MIDWEST.

Region	Percentage of Lakes and Streams Sampled					Total Number Lakes/Streams Sampled
	Acidified (≤ 0 μeq/ℓ)	Extreme Sensitivity (0-40 μeq/ℓ)	Moderate Sensitivity (40-199 μeq/ℓ)	Low Sensitivity (200-499 μeq/ℓ)	Not Sensitive (≥ 500 μeq/ℓ)	
Lakes						
Adirondack[1]	23	17	40	15	5	432
Northern Wisconsin[2]	3	20	19	32	26	276
Northern Minnesota[3]			48	35	17	85
Streams						
N.W. Pennsylvania[4]		22	33	34	11	18
E. Pennsylvania[4]		19	19	31	31	26
Connecticut[5]	4	4	48	44		23
Maine[5]		6	75	19		16
NC/VA[6]		5	59	33	3	38
Jackson Co. (Wis.)[7]		8	35	18	39	80
Oneida Co. (Wis.)[8]		2	11	33	54	195

[1] Pfeiffer and Festa (1980). (1979 data only.)
[2] Eilers et al. (1979).
[3] Glass and Loucks (1980).
[4] Arnold (1981). (Possibility of acid mine drainage being evaluated.)
[5] Haines (1981a, 1981b).
[6] Hendrey et al. (1980). (See text for sampling base.)
[7] Klick and Threinen (1968).
[8] Andrews and Threinen (1966). (Includes only streams with watershed areas ≤ 3 mi².)

TABLE 13. COMPARISON OF MEAN pH AND EXCESS SO_4 FLUXES FROM THE MID 1950s TO 1973, FOR SIX RIVERS IN NOVA SCOTIA AND ONE IN NEWFOUNDLAND.

River	pH	Excess SO_4 meq m^{-2} yr^{-1}	Year
St. Mary's	6.20	42	1954-55
	5.16	60	1973
Roseway	4.66	30	1954-55
	4.28	128	1973
Tusket	5.16	51	195455
	4.38	101	1973
Mersey*	5.82	18	1954-55
	4.78	65	1973
Medway	5.67	29	1954-55
	4.88	78	1973
La Have	5.94	34	1954-55
	5.20	80	1973
Rocky River,	6.15	27	1955-56
Newfoundland	5.3	101	1973

* Discharge data incomplete 1954-55

From: Thompson *et al* 1980.

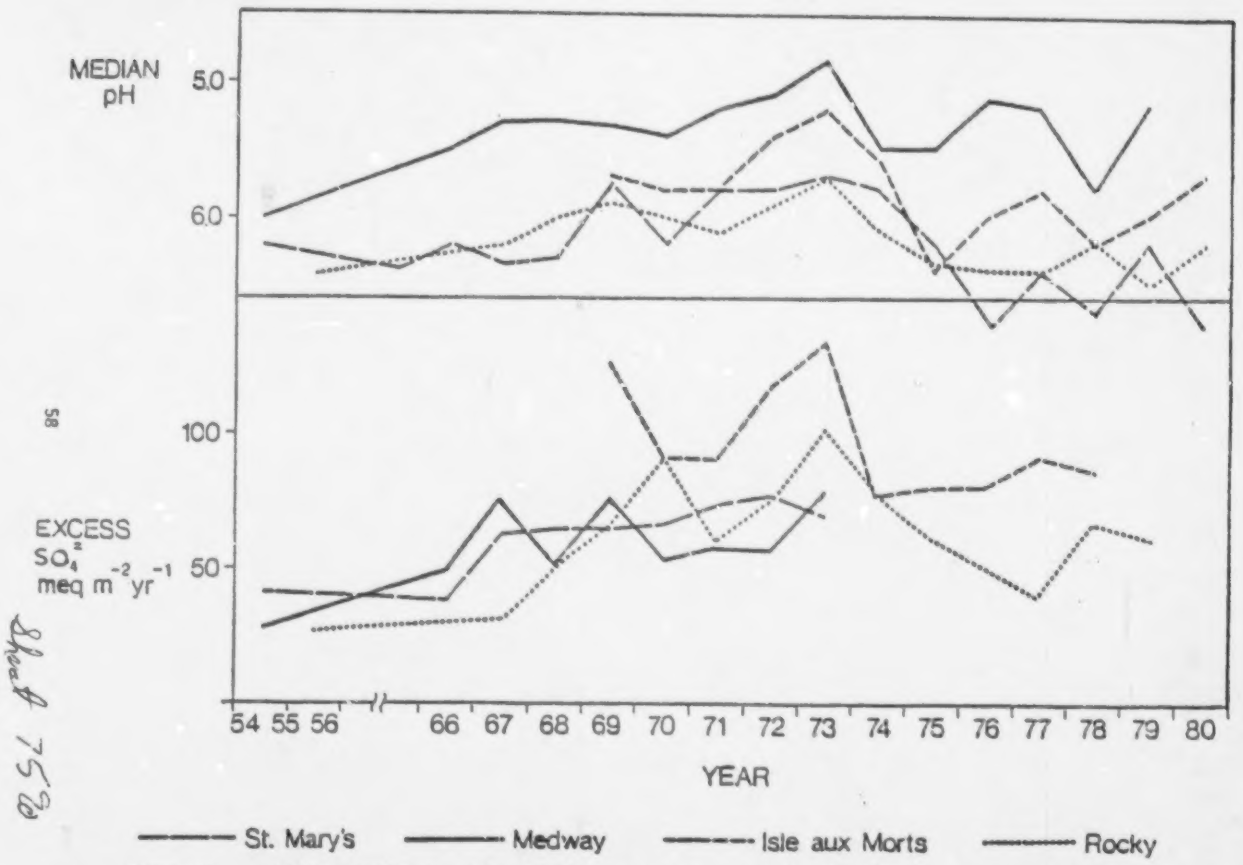


Figure 25. Annual changes in median pH and mean discharge-weighted excess SO_4 for the St. Mary's and Medway Rivers, Nova Scotia, and the Isle aux Morts and Rocky Rivers, Newfoundland, 1954-55 or 1955-56 and 1966-80. (M. Thompson 1981, personal communication.)

Sheet 75%

too much for a very soft-water river such as the Medway. The margin between acceptable and excessive SO_4 loading is small for these and many similar rivers in Nova Scotia and Newfoundland.

Wiltshire and Machell (1981) have reported on a re-survey of 16 lakes in Nova Scotia and New Brunswick which had historical data going back to the 1930s in some cases. Eleven of the lakes are remote from local sources in Halifax and Saint John. Table 14 from their report summarizes the data for 10 remote lakes with the most reliable historical information, and it is apparent that there has been a decline in pH in all cases, most notably since the 1950s. Herman and Gorham (1957) reported a mean pH of 5.7 for precipitation collected in the Kentville, Nova Scotia, area during the early 1950s compared to values of about 4.6 in recent years. Wiltshire and Machell indicate that the surveys are being extended to year-round sampling to determine whether year-to-year variations have contributed to these apparent declines.

Historical Trends in New York State. Studies of lake chemistry in high-elevation lakes of the Adirondack region of New York (Figure 26) have shown a marked decline in the pH of the lakes, compared with data of 40 years earlier (Figure 27). Of the 218 lakes measured in 1975 (Wright and Gjessing 1976) approximately 50% were significantly more acid in comparison to earlier observations. All surveyed lakes are very sensitive to acidification (less than 200 µeq/ℓ alkalinity), and many are already acidified, as indicated by the negative alkalinities (Pfeiffer and Festa 1980).

A positive correlation between increased elevation and reduced pH of ponds and lakes appears to reflect the combined influence of heavier precipitation at higher elevations, the smaller surface acreage and watershed size which characterizes most headwater ponds, the prevalence of granitic bedrock and shallow soil deposits in the higher areas, and the direct impingement of acidic cloud water. The most recent (1975 to 1979) New York State Department of Environmental Conservation surveys (Pfeiffer and Festa 1980) indicate that 25% of the lakes (comprising about 5% by area of the sampled waters) were at a "critical" pH level, below 5.0. Overall, 7.9% of the lakes in the Adirondacks were acidified from acid precipitation (228 lakes), totaling 3.9% of the water acreages. From these studies, there is evidence suggesting that decreases in pH have occurred over a wide range of lake pH values. A set of 138 lakes in the Adirondacks is summarized in Figure 28.

The Hinckley Reservoir, a municipal water supply reservoir in New York state, built around 1910, receives the drainage of West Canada Creek in the southwestern Adirondack Mountains. Water quality records have been maintained since 1924. Results for total hardness and alkalinity over the period 1924 to 1975 indicate a significant long-term decline, which may have begun before 1920. Short-term upward and downward shifts in alkalinity and hardness occur over the period, apparently increasing in the early 1960s, due to drought conditions (C. L. Schofield, personal communication). The fact that alkalinity and hardness tend to increase and decrease together seems unusual, and suggests that if the response is due to acidic input, it is associated with complex geochemical alteration.

TABLE 14

APPARENT CHANGES IN SUMMER pH VALUES IN LAKES IN NOVA SCOTIA AND SOUTHERN NEW BRUNSWICK DURING THE PERIOD 1940-1979

	pH			Δ pH		Calculated alkalinity change in μeq/ℓ[d]	
	ca 1940[a]	1950s[b]	1979[c]	pre-1950s	post-1950s	pre-1950	post-1950
Boarsback (N.S.)	4.7	4.7	4.4	.0	-.3	0	-20
Jesse (N.S.)	6.5	6.5	5.8	.0	-.7	0	-14
Lily (N.S.)		6.5	5.8		-.7		-14
Kerr (N.B.)	6.8	6.6	6.0	-.2	-.6	-12	-16
Creasey (N.B.)	6.7	6.7	6.0	.0	-.7	0	-21
Tedford (N.S.)	6.3	6.6	6.3	+.3	-.3	5.5	- 5
Sutherland (N.S.)		7.0	6.3		-.7		-41
Gibson (N.B.)	7.0	6.7	6.4	-.3	-.3	-25	-18
Black Brook (N.S.)		6.8	6.4		-.4		-20
Cooper (N.S.)		7.3	7.0		-.3		-55

[a] Data from Smith (1938a,b, 1948, 1952, 1961).

[b] Data from Hayes and Anthony (1958).

[c] This study.

[d] Liljestrand, H.M., personal communication. PCO_2 assumed - $10^{-3.5}$ atm. with bicarbonate as major buffer. Negative alkalinity is a positive acidity.

From: Wiltshire and Machell (1981).

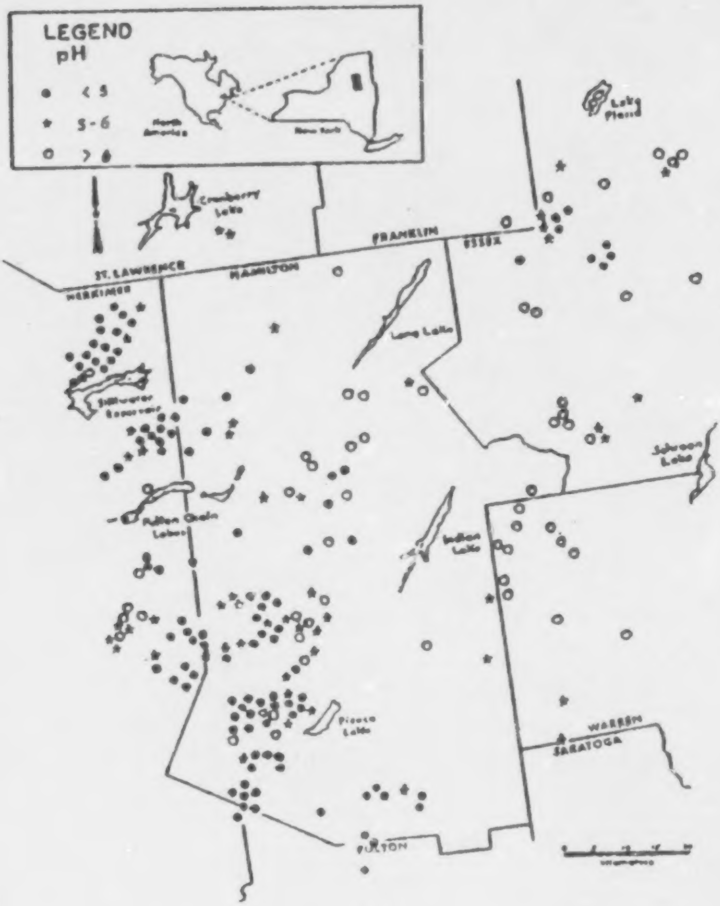

LEGEND
pH
● < 5
★ 5 - 6
○ > 6
North America
New York
Lake Placid
Cranberry Lake
FRANKLIN
ESSEX
ST. LAWRENCE
HAMILTON
HERKIMER
Long Lake
Stillwater Reservoir
Schroon Lake
Fulton Chain Lakes
Indian Lake
Piseco Lake
WARREN
SARATOGA
FULTON

Figure 26. Geographic distribution of pH levels measured in Adirondack lakes higher than 610 meters elevation, June 24-27, 1975 (Schofield 1976).

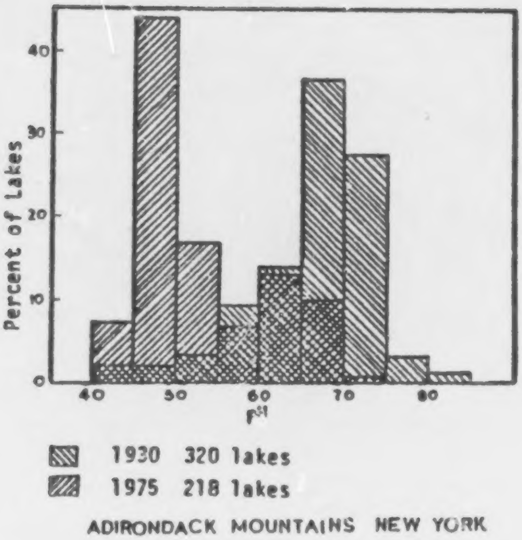


Figure 27. Comparison of lake pH, 1930 to 1975, for the Adirondack Mountains area of New York (Wright and Gjessing 1976).

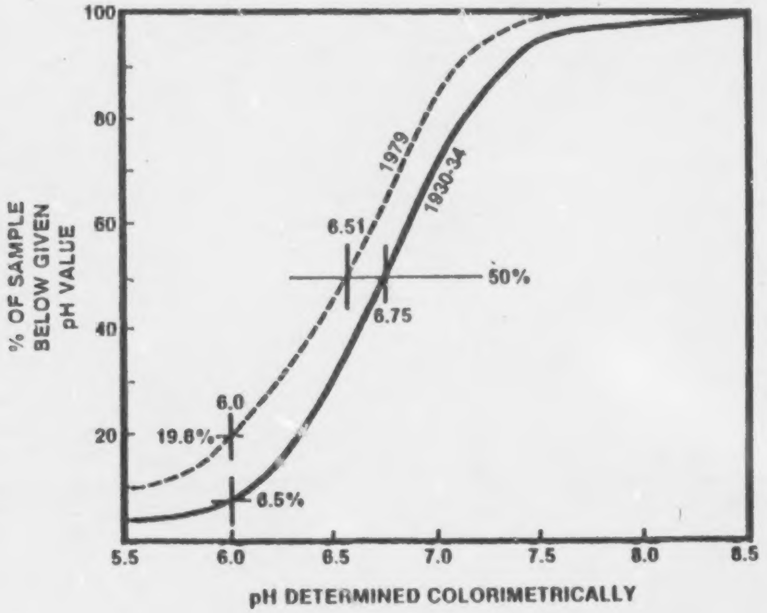


Figure 28. Cumulative comparison of historic and recent pH value for a set of 138 Adirondack Lakes, New York (Pfeiffer and Festa 1980).

pH Changes in Maine and New England. Summer pH measurements are available for 1368 of the several thousand lakes in Maine, over the interval from the 1930s to the 1970s. The results show a decreased pH, on the average of from about 6.85 in 1937 to about 5.95 in 1974, an eight-fold increase in H. Roughly three-fourths of the decrease occurred between 1950 and 1960, corresponding to the period in which the acidity of precipitation may have increased most rapidly (Haines, 1981b).

A preliminary analysis of 300 headwater ponds and streams in the six New England states shows that alkalinity readings of less than 200 μeq/ℓ cover most of the regions examined, with widespread readings below 20 μeq/ℓ (Figure 29). For comparison, Harvey *et al*. (1981) have considered lakes with alkalinity readings below 200 μeq/ℓ as highly sensitive to acidification (Haines, 1981b).

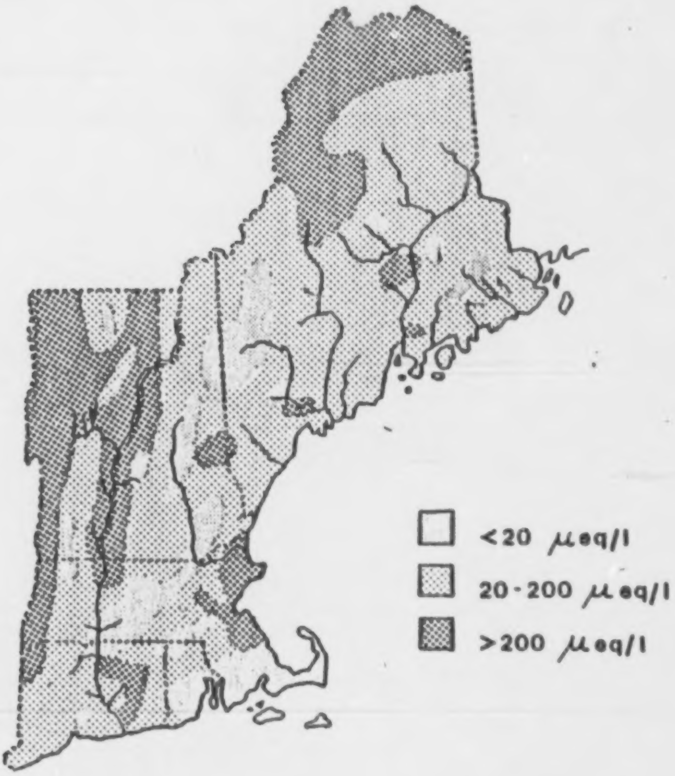


Figure 29. Surface water alkalinity of New England states (Haines, 1981a, 1981b).

Time-Trend in New Jersey. Johnson (1979) described a 17-year trend toward acidification of headwater streams in the New Jersey Pine Barrens which drain relatively undisturbed watersheds (Figure 30). The decline in pH is a statistically significant trend with time, and has amounted to approximately 0.4 units (pH) over the period - an estimated increase in H concentration of about 50 µeq/ℓ. In the sandy soils of this region, relatively little neutralization of acidic input occurs by ion exchange or mineral weathering as precipitation moves through the soil. The low level of neutralization is evidenced by the low pH of shallow groundwater, averaging 4.3 for 78 samples in 1978 through 1979. One reason for the great variability in pH values is thought to be the timing and variable to pH of individual storms (see following discussion of seasonal and episodic pH changes).

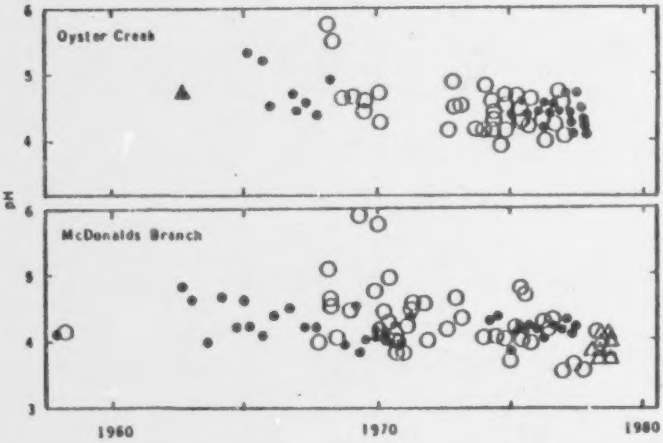


Figure 30. New Jersey stream pH, 1958-1979, Oyster Creek and McDonalds Branch. Closed circles represent samples in which anion and cation equivalents balanced and calculated and measured specific conductances were equal. Open circles are samples for which the chemical analyses were incomplete or for which discrepancies in anion and cation and conductivity balances could not be attributed to errors in pH. The closed triangle represents the average pH determined in a branch of Oyster Creek in a 1963 study. Open triangles are monthly means of pH data collected weekly from May 1978 to January 1979 during a University of Pennsylvania trace metal study (Johnson 1979).

One possible cause of the decline is the apparent increase in acid content of precipitation over the last two decades, as described for other areas in the northeastern United States. Some precipitation pH data suggest a trend toward lower pH of precipitation in southern New Jersey (Johnson 1979). Precipitation samples, collected at several sites in the Mullica and Cedar Creek basins in 1970 through 1972, had an average pH of 4.4, and samples collected near Oyster Creek for 7 months in 1972 had an average pH of 4.25. From May, 1978 to April, 1979, the average pH of weekly precipitation samples at McDonalds Branch was 3.9. The SO_4 concentrations in McDonalds Branch and Oyster Creek are consistent with the hypothesis of an atmospheric source of acid, since SO_4 is the major anion balancing H in the precipitation.

pH and Alkalinity Trends in North Carolina. Measurements of 38 streams in western North Carolina reported by Hendrey et al. (1980) showed a decrease in pH and alkalinity in 80% of the streams surveyed between 1960-63 and June and July, 1979. The distributions of apparent pH and alkalinity changed substantially over the 15 to 19 years between samples (Figures 31 and 32). Mean hydrogen ion concentrations changed from pH 6.77 in the early 1960s, to pH 6.51, in 1979 - an 82% increase in hydrogen ion concentration. Mean alkalinity values have also declined significantly since the early 1960s, from 116 μeq/ℓ (corrected for differences in methods), to 80 μeq/ℓ in 1979, with 71% of the 1979 values being lower than the earlier (corrected) values. Additional data are needed to confirm these observations, which represent the most sensitive streams in the area.

In the Great Smoky Mountains National Park, other symptoms have been observed in an independent study (Herrmann and Baron 1980). Acid runoff at pH as low as 4.3 in perennial mountain streams has produced elevated aluminum concentrations (to 1.8 mg/ℓ from 0.4 in larger streams). Inhibiting effects upon population densities of benthic macroinvertebrates, and upon brook trout populations, have been linked to the acidic loadings. Similarity of edaphic conditions in the park, and in the Adirondack Lake region of New York, was noted.

Seasonal and Episodic pH Depression

While survey data, both current and historical, can document long-term trends in a synoptic sense, the samples usually represent one (or a few) measurements at any one location and are usually taken in the summer. This limited sampling period provides no record of pH and other chemical changes which take place in relation to seasonal cycles or major weather events. If these changes coincide with sensitive periods in the life cycles of fish, e.g., spawning and hatching, significant mortality can occur. Individual pH values during the summer usually do not reflect these aspects of the dose/ response relationship. In addition, occasional pH depressions may signal the beginning of lake or stream transition to acidified status (see later discussion). The following data describe recent results on episodic pH depressions; the extent to which these phenomena occurred in the past is not known, but comparisons can be made with "control" areas having low acidic deposition.

pH Depression During Spring Runoff in Ontario. Detailed surface-water chemistry studies are being conducted in lakes near Dorset, Ontario, just southwest of Algonquin Park, an area within the Precambrian shield.

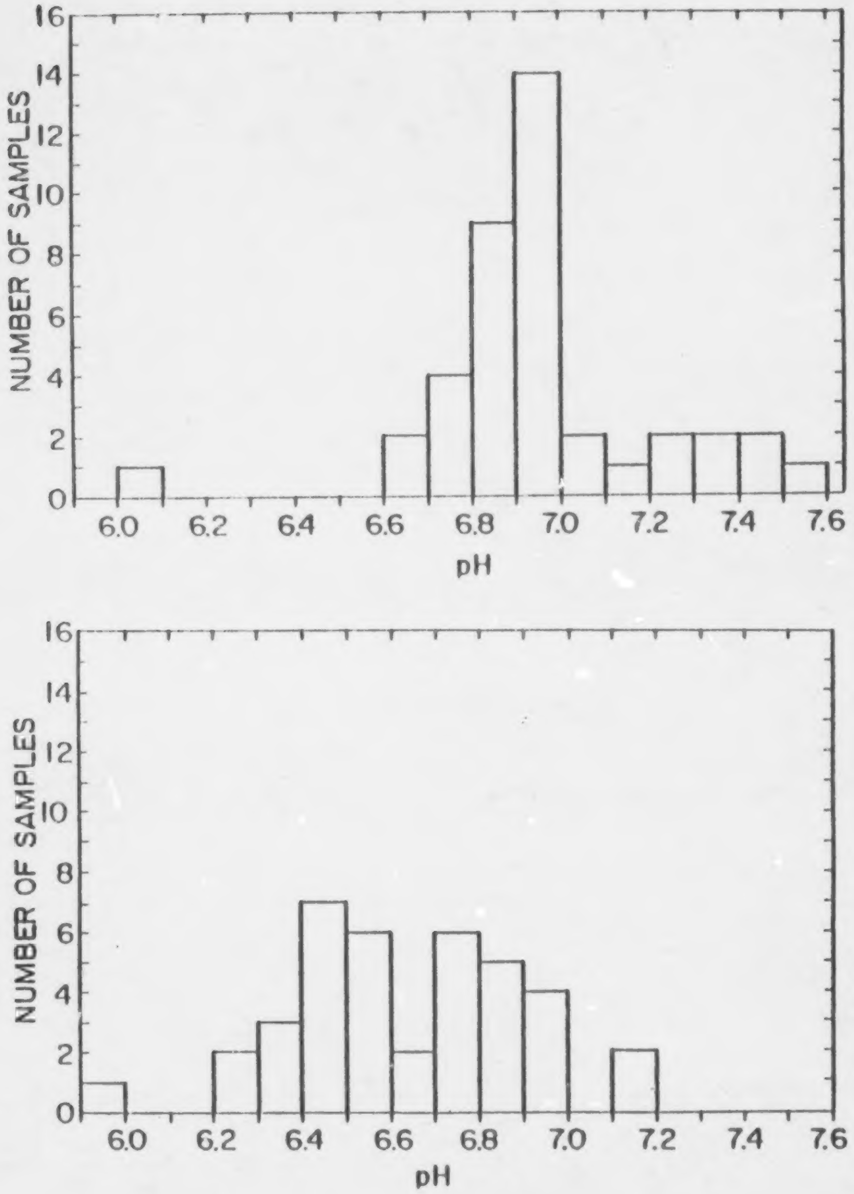
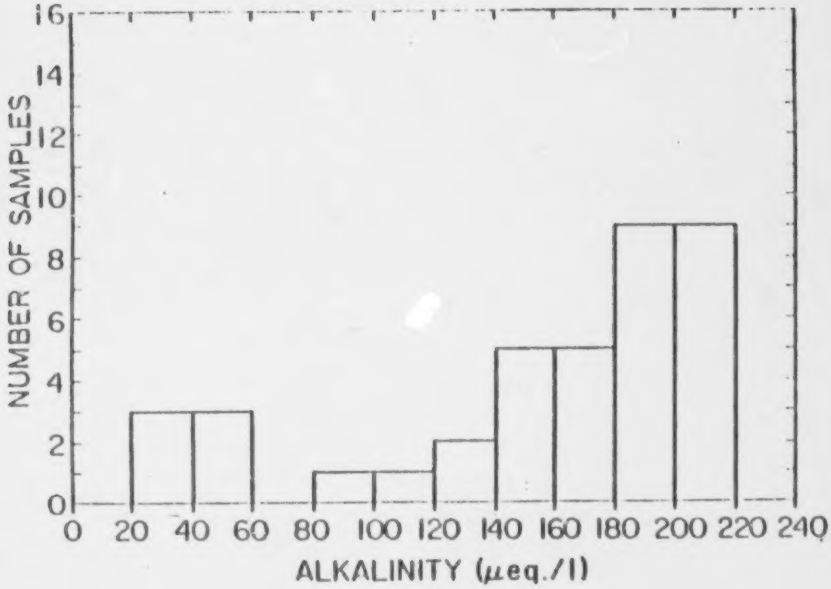


Figure 31. Distribution of pH of North Carolina streams June, July, August 1960-63 (upper), compared with June, July 1979 (modified from Hendrey et al. 1980).



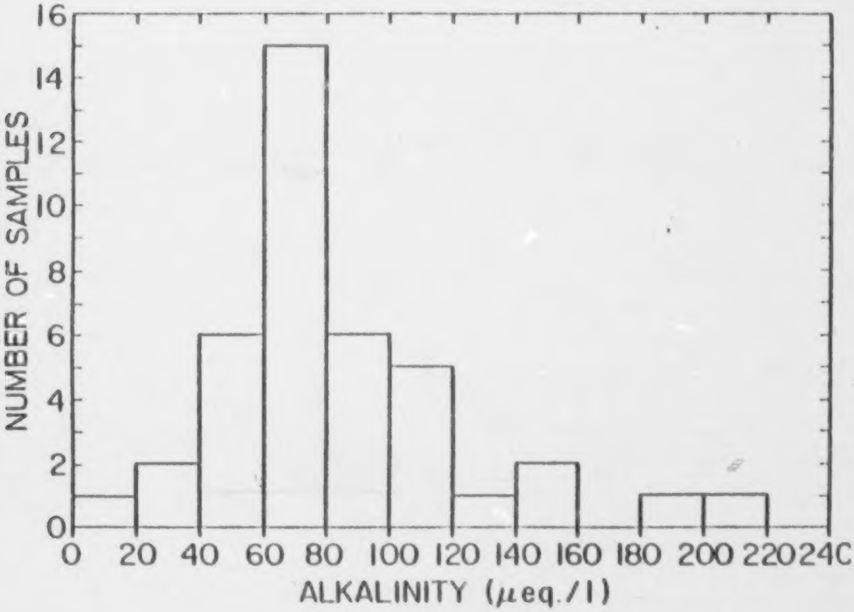


Figure 32. Distribution of alkalinity of North Carolina streams June July, August 1960-63 (upper), compared with June, July 197 (modified from Hendrey *et al*. 1980).

Jeffries et al. (1979) compared pH values of a series of small streams in the study area, before and during spring runoff (Table 15). The pH of the lake outflows demonstrates that the surface waters, at least, of the entire lakes were acidified during this period of time. The lowest pH values observed, 4.1 to 5.1, are within a range capable of causing damage to aquatic life, particularly fish. As much as 76.7% of the measured yearly acid discharge from the streams ran off in April. Figure 33 shows a typical hydrograph and pH response for one of the streams during the snowmelt period. Scheider et al. (1979b) further showed that the pH of streams was depressed for periods of as little as a few hours during times of heavy runoff, during the summer months (Figure 34).

TABLE 15

pH OF STREAMS IN MUSKOKA-HALIBURTON, ONTARIO, CANADA:
STREAM pH IS GIVEN PRIOR TO SPRING RUNOFF (MID-MARCH 1978)
AND AT MAXIMUM RUNOFF (MID-APRIL 1978)

Watershed	Stream	pH Mid-March	pH Mid-April
Harp Lake	3	6.1	5.1
	3A	6.0	5.6
	5	5.9	4.8
	6	6.2	5.3
	6A	5.4	5.0
	Outflow	6.3	5.0
Dickie Lake	5	4.6	4.3
	6	4.6	4.4
	11	4.9	4.1
	Outflow	5.6	4.9
Chub Lake	1	5.8	5.1
	2	5.2	4.7
	Outflow	5.5	4.8
Red Chalk Lake	1	6.1	5.6
	2	4.5	4.3
	3	6.0	5.5
	4	6.2	5.5
	Outflow	6.1	5.9
Maple Lake	Maple Creek	6.2	5.8
Lake Simcoe	Black River (at Vankoughnet)	6.3	5.9
Lake of Bays	Oxtongue River	6.3	6.1

From. Jeffries et al. (1979)

Heavy fall rains also cause depressed pH in runoff for days at a time. Scheider (1981, personal communication) observed as much as 25.8% of the total annual hydrogen ion runoff, from small watersheds, in October. The biological implications of these periodic pH depressions are now being studied in detail.

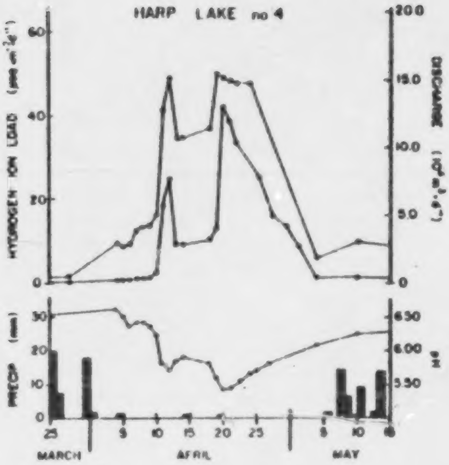


Figure 33. Discharge (°), hydrogen ion load per unit area (°), pH (lower graph), and depth of precipitation for each day that a precipitation event occurred for Harp Lake no. 4. Daily H+ load to the respective lakes can be calculated by multiplying by the watershed area: lake area (A_d/A_o); where A_d is the area of the subwatershed and A_o that of the lake; A_d/A_o is 1.85 for Harp Lake no. 4. From Jeffries et al. (1979).

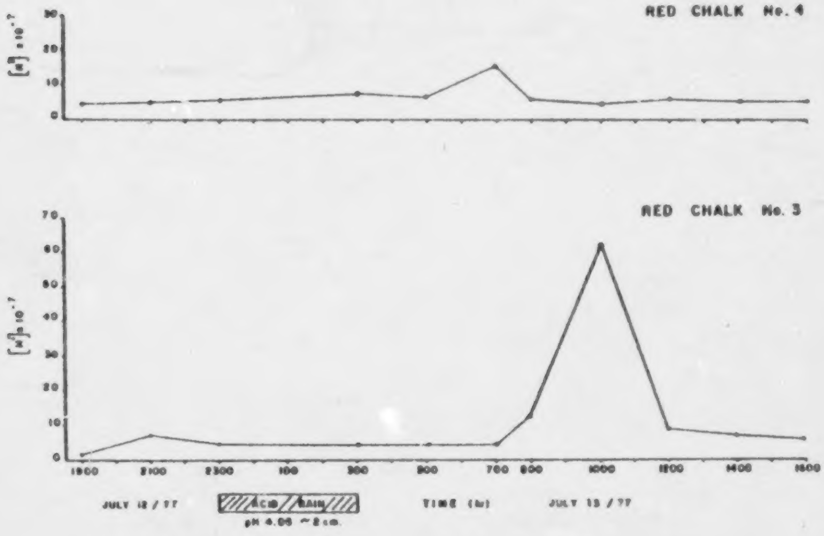


Figure 34. Hydrogen ion content of streams draining Red Chalk Lake watersheds no. 3 and no. 4 (Dorset, Ontario) showing effects of a 2 cm rainfall (pH 4.06) between 11:00 p.m. July 12, 1977 and and 3:00 a.m. July 13, 1977 (Scheider et al. 1979b).

pH During Flushing Events in West Virginia. Seasonally low pH, and a regular pattern of pH depression, have been documented for the Little Black Fork and Shavers Fork Rivers by the U.S. Forest Service in Monongahela National Forest (Dunshie 1979). The tributaries and the river are poorly buffered and subject to rapid changes in water quality due to the influence of the poorly-buffered sandstone geology of the watershed. The lowest pH values in both streams (Little Black Fork is a control area with no logging or coal mining) normally occur during the winter and early spring, apparently because of snowpack melting. The highest pH occurs during low stream flow periods in the summer and fall. Even though this is the period of highest deposition (see below), more extensive contact between soils and precipitation may lead to greater neutralization than during winter or spring.

Nearly 13 years of pH data have been collected at the Bowden Fish Hatchery river intake on the Shavers Fork River, showing a declining trend from a high in the summer to a low in the spring. This is important for aquatic organisms and has been measured in other lightly buffered streams. This pH trend occurs in streams and tributaries independent of watershed disturbance by mining.

The effect of rainfall on river pH is more apparent when individual events are examined. A graphic presentation, pairing daily river and precipitation events with pH during summer and winter periods, is shown in Figure 35. Daily precipitation accumulation and discharge are also shown. The data suggest that during the growing season a storm event, with a subsequent increase in discharge, lowers river pH below the natural non-storm daily variation. The magnitude of this downward shift is dependent upon rainfall characteristics (pH, amount, intensity, and area distribution) and antecedent soil moisture. Downward shifts in river pH ranging from six to nine-tenths of a unit occurred on July 11 and 26, and on August 15 and 25. On three of these days, at least 3.3 cm of rainfall fell within a 48-hour period; pH of the rainfall for these dates ranged from 3.7 to 4.2.

Minnesota, Wisconsin and Michigan. The possibility of effects from acidic deposition on the BWCAW of northern Minnesota were assessed during a synoptic study of lakes and streams, before and after the snow season, 1978-79. Studies of several lakes and streams during the snowmelt period revealed relatively large decreases in pH and alkalinity in the surface waters. pH depressions of as much as 0.8 unit were noted (Figure 36). Changes in water quality occurred concurrent with the spring melt and the release of accumulated materials (SO_4, NO_3, H). In addition, there were contributions from watershed soils (Ca) (Glass 1980 and Glass and Brydges 1981).

ALTERATION OF BIOTIC COMPONENTS

Many changes in biota have been linked to acidification. In some instances a causal relationship with depressed pH has been established, but in the majority of cases, the observed changes in biota have simply been correlated with observed changes in pH and causality has not been established. For most biological communities, acidification has been

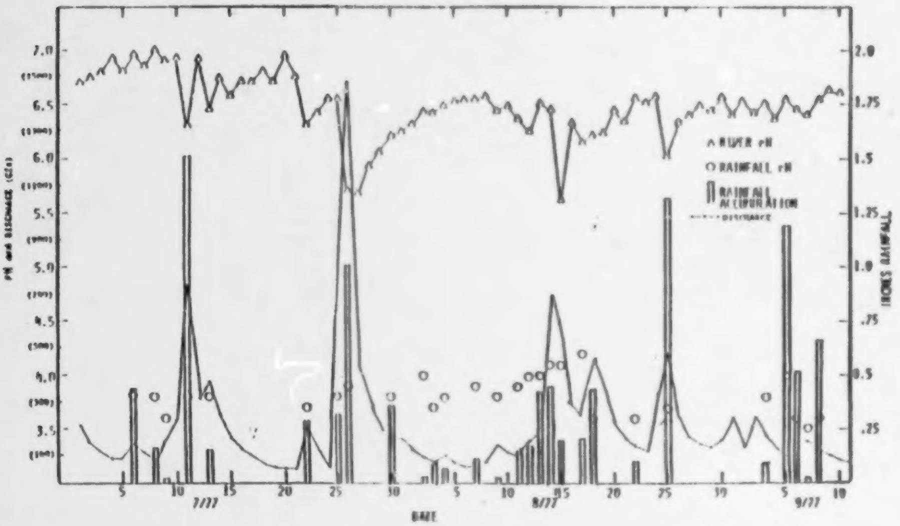


Figure 35. Mean daily pH for the Shavers Fork River at Bemis, West Virginia, and precipitation event pH and accumulation at Arborvale, West Virginia (Dunshie 1979).

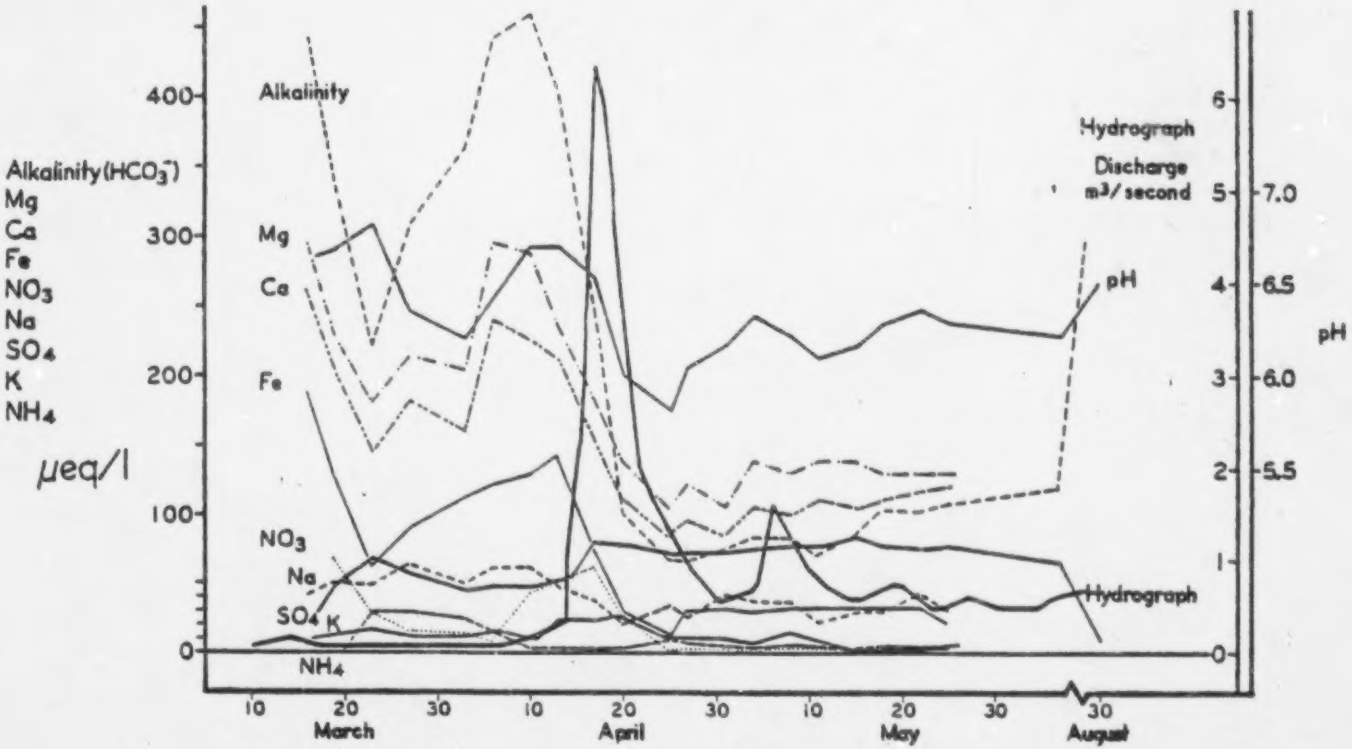


Figure 36. Snowmelt-runoff hydrograph and changing water quality for Filson Creek, Minnesota, Boundary Waters Canoe Area Wilderness region (Glass and Brydges 1981).

accompanied by decreases in species diversity and changes in species dominance. Acidification may be accompanied by species extinctions or decreases in overall community standing stocks. Generalized summaries of aquatic organisms' response to low pH are given in Figures 37 and 38 and are presented here as a simplified overview of the complex interactions described below (Eilers and Berg 1981).

Definitive experiments are required to demonstrate whether such changes are directly attributable to increases in hydrogen ion concentration or whether they are attributable to secondary ecosystem interactions, such as elevation of aluminum levels or disruptions of normal food chains. In spite of incomplete understanding of the actual mechanisms underlying observed changes accompanying acidification, it appears that acidification of surface waters alters, if not destroys, the species composition of aquatic ecosystems.

Effects on Algae

The free-floating (planktonic) and attached (benthic) algae are the major primary producers in most aquatic ecosystems and directly or indirectly provide most of the food for zooplankton and, ultimately, for fish.

Evidence gathered mainly from synoptic surveys in Scandinavia, Canada, and the United States has demonstrated that the species diversity of benthic and planktonic algal communities is reduced in acidified lakes. Yan and Stokes (1976) observed only nine species of phytoplankton in a single sample from Lumsden Lake (pH 3.8), in the La Cloche Mountains in Ontario, but observed over 50 species in each of two nearby non-acidic lakes. Diversity indices for the La Cloche Mountain lakes decrease sharply as pH falls below 5.6 (Kwiatkowski and Roff 1976), while species numbers decrease most rapidly at a pH level of about 5.5 in Scandinavian lakes (Almer et al. 1978, Leivestad et al. 1976).

Some long-term functional adaptations to acidic environments may occur. Raddum et al. (1980) have suggested that such a mechanism explains the observation that a group of relatively recently acidified clearwater lakes in Norway have less diverse phytoplankton assemblages than naturally acidic, humic lakes. Additionally, the bioavailability and toxicity of trace metals may be lower in the brownwater acidic lakes because of complexation of metals with humic materials.

Although species diversity of phytoplankton generally decreases with increasing acidity, biomass (Yan 1979) and productivity (Almer et al. 1978, Schindler 1980) are probably not reduced by acidification. Phosphorus, the nutrient that normally limits high phytoplankton productivity in soft-water lakes, may, however, be immobilized in acidic lakes because of interaction with aluminum and humic material (Almer et al. 1978).

Phytoplankton communities of non-acidic oligotrophic lakes in eastern Canada are typically dominated by chrysophytes (Schindler and Holmgren 1971), or by diatoms (Duthie and Ostrofsky 1974). In contrast, strongly acidic lakes are generally dominated by dinoflagellates. In Sweden, the Pyrrhophyta, especially the dinoflagellates, formed 85% of the biomass in

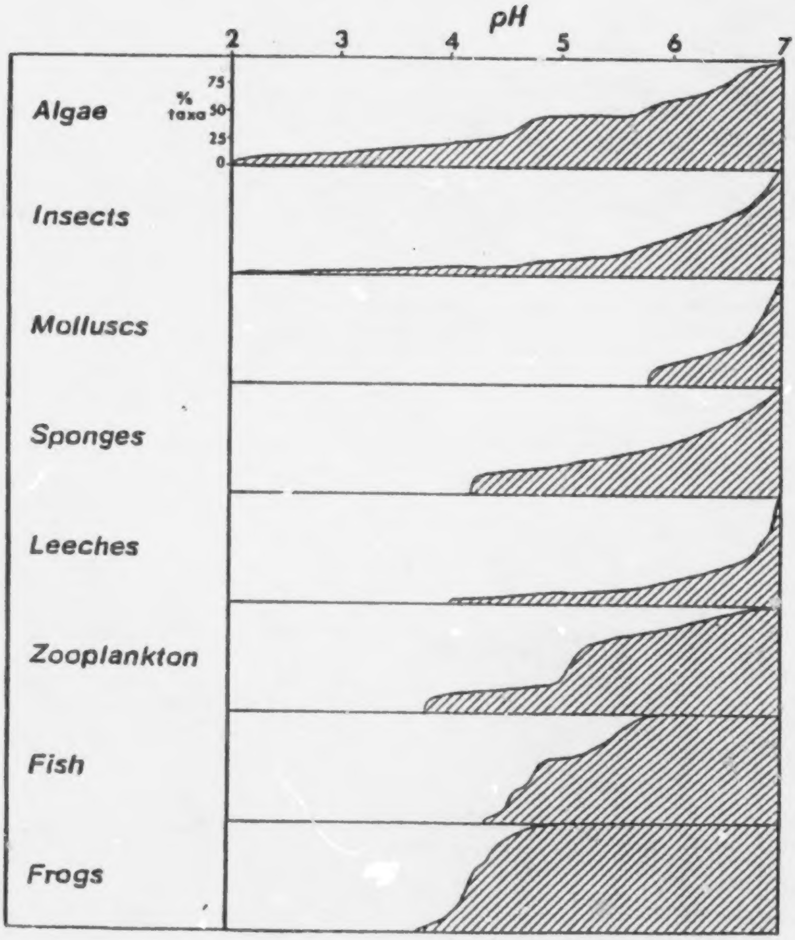
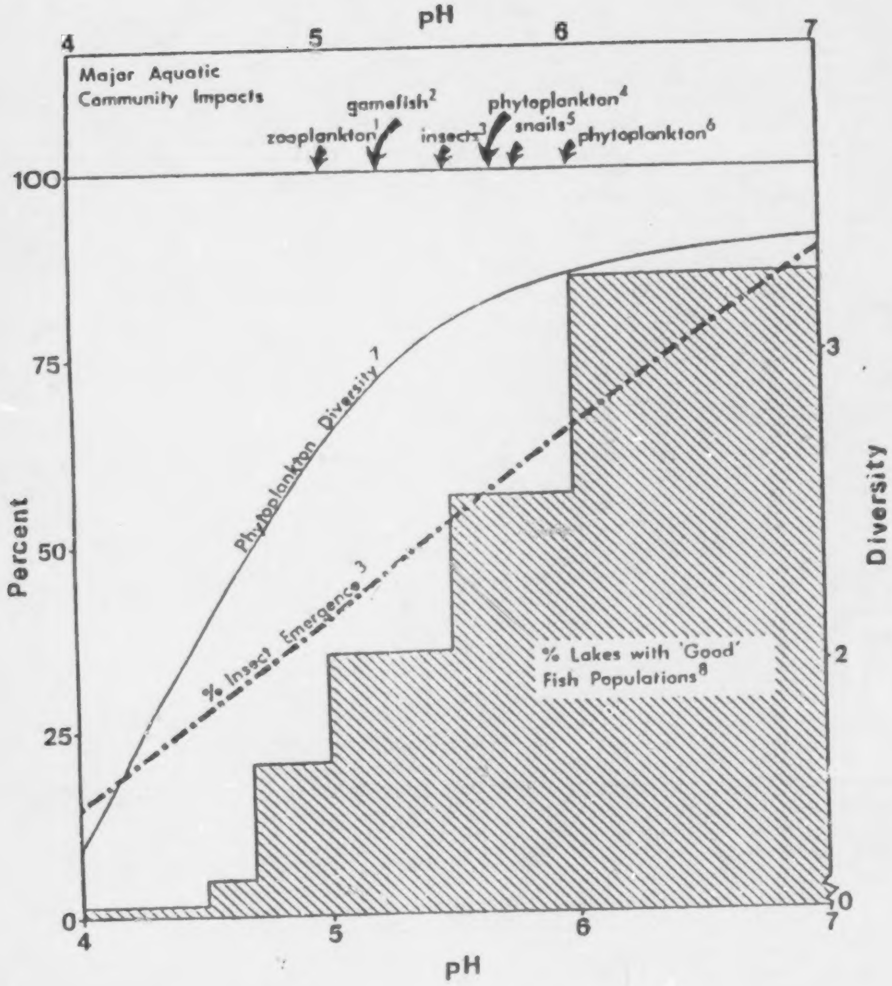


Figure 37. Relative number of taxa of the major taxonomic groups as a function of pH. (Eilers and Berg 1981.)



1 Sprules (1975) - Ontario
2 Beamish (19 6) - Ontario
3 Bell (1971) - Laboratory TL_{50}
4 Yan and Stokes (1978) - Ontario
5 Okland (1969) - Scandinavia
6 Wright et al. (976) - Norway
7 Kwiatkowski and Roff (1976) - Ontario
8 Snekvik (1974) - Norway

Figure 38. Generalized response of aquatic organisms to low pH. (Eilers and Berg 1981.)

lakes of pH 4.6-5.5 (Dickson *et al*. 1975). Of 14 lakes in central Ontario, dinoflagellates formed between 30 and 70% of the phytoplankton biomass in four acidic lakes (pH 4.2-4.8), but only 2-30% of the biomass in ten lakes with pH levels of 5.8-6.8 (Yan 1979).

In certain poorly buffered lakes, some of the phytoplankton species may interfere with recreational use of the lakes. In five lakes in Ontario and New Hampshire with pH 5.5 to 6.2, for example, obnoxious odors developed during the summers of 1978, 1979, and 1980. The odors have been shown to be caused by the growth of the planktonic *Chrysochromulina breviturrita*. This species was first discovered in 1976, but it is now known to inhabit more than 40 lakes in Ontario, most of which are acidic (Nicholls *et al*. 1981). The "invasion", and associated odor production, by this organism is apparently a recent phenomenon. Although the relationship between lake acidification and the proliferation of this species has not been proven, data collected thus far show that the growth of this species, and the serious odor production, is generally restricted to acidic lakes.

The benthic algal communities of acidified lakes are characterized by increased growth of filamentous algae and decreases in the importance of diatoms. In Sweden and in Ontario (Stokes 1981, Schindler 1980), unusually dense and extensive mats of algae, (mainly *Mougeotia* and *Zygonema*) proliferate in the littoral zone, either associated with macrophytes (Grahn *et al*. 1974, Hultberg and Grahn 1976, Hendrey *et al*. 1976) or on other surfaces. The accumulations of algae may reduce light availability to macrophytes, change microclimates for benthic macroinvertebrates, and reduce fish spawning and feeding habitats.

Effects on Aquatic Macrophytes

Information on the effects of acidification on the macrophyte communities of soft-water lakes is still incomplete. Scandinavian investigators have suggested that when lake pH is depressed, typical macrophyte dominants are replaced by very dense beds of *Sphagnum* (Grahn *et al*. 1974, Hultberg and Grahn 1976, Hendrey *et al*. 1976). The loss of some macrophyte species and the correlative increase in *Sphagnum* abundance may be indirectly related to depressed pH through changes in inorganic carbon availability (Steemann-Nielsen 1944, 1946; Raven 1970).

In Scandinavia the decline of macrophyte species and the concurrent *Sphagnum* invasion begin as pH falls to about 6.0 and proceed rapidly when pH falls below 5.0. In Lake Colden in New York (pH 4.9) *Sphagnum* is abundant (Hendrey and Vertucci 1980); however, other Adirondack lakes show no macrophyte community changes (Peverly, personal communication). In Beaverskin Lake in Kejimkujik National Park in Nova Scotia, a clear lake of pH 5.3, Kerekes (1981) has reported extensive *Sphagnum* growth. In Ontario lakes some species of *Sphagnum* have been identified (Harvey *et al*. 1981) but accumulations as dense as those recorded in Scandinavia have not been observed. By release of hydrogen ions and polyuronic acids into their environment, *Sphagnum* sp. acidify their immediate surrounding (Clymo 1963, Crum 1976). Finally, *Sphagnum* moss coverage of littoral zones creates a unique habitat which is considered unsuitable for some species of benthic invertebrates, or for use as fish spawning and nursery ground

(Hultberg and Grahn 1976). Additionally, dense beds of *Sphagnum* and filamentous algae may reduce the appeal of freshwater systems for certain recreational activities.

Effects on Zooplankton

Four major groups of animals contribute to zooplankton communities: protozoans, rotifers, crustaceans, and insects. They provide food for many species of fish, particularly for younger individuals, and thus are an essential component of the aquatic food chain, transferring energy and materials from the primary producers (algae) to consumers, including fish and man. Acidification apparently results in reduced zooplankton biomasses as both the numbers and average size of community members are reduced (Yan and Strus 1981). Food availability to higher trophic levels will in consequence be reduced.

Acidification of lakes is accompanied by changes in the occurrence, abundance and seasonal succession of species, and in the diversity of crustacean (and other) zooplankton components. It is often assumed that the direct cause of these changes is differences in tolerance among zooplankton species to increased H concentration. However, acidification may also: increase the transparency, thus affecting the light regime, of lakes; increase the concentration of chemical substances, including potential toxicants; and produce quantitative and qualitative changes in zooplankton predator and prey species (Harvey *et al*. 1981). Hence, the immediate causes for the changes in zooplankton communities that do occur, while linked to acidification, may be quite complex.

The most important components of zooplankton communities are usually the rotifers and crustaceans. Of these, the crustaceans usually form 90% of the biomass (Pederson *et al*. 1976), while rotifers, because they have shorter generation times, may be responsible for 50% of the zooplankton productivity (Makarawicz and Likens 1979). Studies from very acidic lakes, such as acid-mine drainage lakes (Smith and Frey 1971) or the Smoking Hills Lakes of the Northwest Territories (Havas 1980), indicate that some species of rotifers can survive when all crustacean zooplankton have been eliminated by acidification (Smith and Frey 1971). Thus, rotifers may become more important contributors to the zooplankton community as lakes acidify. Available studies on the effects of acidification on rotifer populations are contradictory: both decreases (Roff and Kwiatkowski 1977) and increases (Yan and Miller 1981, Malley *et al*. 1981) in standing stocks have been observed in acidic lakes.

The diversity of zooplankton communities has been reported in several studies to be greatly reduced by acidification (Sprules 1975a, Raddum *et al*. 1980). Whereas non-acidic lakes typically contain approximately ten species of planktonic crustacea in mid-summer collections, Sprules (1975b) observed that species diversity of acidic lakes in the La Cloche Mountains in Ontario was drastically reduced. In several cases only a single species, *Diaptomus minutus*, remained.

Some predacious zooplankton, especially cyclopoid copepods (Raddum *et al*. 1980) and *Epischura lacustris* (Malley *et al*. 1981), are very sensitive to acidification, and are often absent from acidic lakes. Densities of other predators such as some species of *Chaoborus* (Eriksson *et al*. 1980) and *Heterocope saliens* (Raddum *et al*. 1980) apparently increase. The significance of these changes in predator populations to zooplankton community structure is not yet understood although they may be important (Eriksson *et al*. 1980).

Effects on Aquatic Macroinvertebrates

Numerous aquatic macroinvertebrates are known to be affected by the acidification of water. While in some cases an entire phylum appears to be affected, in other situations susceptibility is species-specific. Evidence indicates that molluscs, in general, are highly susceptible to pH change (Raddum 1980, Okland 1980, Wiederholm and Eriksson 1977), often being restricted to habitats with pH greater than 5.8 to 6.0. Similarly, oligochaetes have been found at lower densities in acid waters (Wiederholm and Eriksson 1977).

Sensitivity to low pH has been inferred from field distribution for certain Arachnida, Crustacea, and Insecta. Arachnids were only briefly mentioned by Grahn and his co-workers (1974): acarina were absent in waters with pH values below 4.6. *Gammarus lacustris* was absent from waters with pH below 6.0 (Okland 1969), while the crayfish, *Astacus astacus*, was rare in lakes where the summer pH value was less than 6.0 (Svardson 1974). Orders of Insecta exhibit a wide range of sensitivities to pH. While the number of species of Ephemeroptera and Plecoptera appear to be positively correlated with pH, larvae of Chironimidae, Hemiptera and Megaloptera are often abundant in acid lakes (Almer *et al*. 1978). Hutchinson *et al*. (1978) reported an extreme example of tolerance. They observed the larvae of red chironomids, *Chironomus riparius*, in waters of pH 2.2 in the Northwest Territories.

Although the field studies mentioned above provide evidence of the effects of acidification on certain species, in only two studies has the pH of a natural system been altered, and the impacts on invertebrates noted. The documented effects of decreased pH include the disappearance of *Mysis relicta* in Lake 233, an experimentally acidified lake in the Experimental Lakes Area (Malley 1981), elimination or reduction of Ephemeroptera populations in a stream in the Hubbard Brook Experimental Forest in New Hampshire (Fiance 1978, Hall *et al*. 1980), and decreased emergence of some species of Plecoptera, Trichoptera and Diptera in the same stream (Hall *et al*. 1980). Those species with acid-sensitive life stages (such as emergence in insects) that can coincide with snowmelt or other events, such as flushing, may be especially sensitive to acid precipitation.

It is important to note, in considering the distribution of the above species in relation to waters of varying pH, that no causative relationship between hydrogen ion concentration and the observed changes has been determined as yet. Other factors vary with pH, including concentrations and availability of nutrients, bicarbonate and various metals. From the results available, however, it appears that molluscs (perhaps because of their requirement for calcium), and moulting crustaceans (perhaps because of their large demand for calcium at the time of moult), are the macroinvertebrates most sensitive to low pH levels. It is still unclear why certain groups of aquatic insects are more sensitive than others.

Effects on Microorganisms

The decomposition of fixed carbon, both allochthonous and autochthonous organic matter, is in large part determined by microbial processes in the water column and in the surface layers of sediment. Several studies have demonstrated that rates of decomposition of organic matter are decreased in acidified waters. In a laboratory study, for example, Bick and Drews (1973) demonstrated that as pH was lowered, the number of bacteria and protozoans decreased, populations of fungi increased, and the rates of decomposition and nitrification were reduced. Traaen (1980) measured decomposition rates of homogenized birch litter and glucose/ glutamate mixtures. When the pH was decreased from 7.0 to 3.5, litter decomposition dropped to 30% of control levels, and a shift from bacterial to fungal dominance was observed. Traaen (1980) further observed that rates of weight loss of birch leaves and aspen sticks after one year in the laboratory or one to two years in field situations were significantly lower at pH levels less than 5.0 than at levels greater than 5.0.

Reductions in numbers of heterotrophic bacteria have been observed previously in aquatic habitats acidified by acid mine drainage (Tuttle *et al*. 1968 and 1969, Thompson and Wilson 1975, Guthrie *et al*. 1978). Caution must be exercised, however, in extrapolating results from acid mine drainage studies to situations where the source of protons is atmospheric. The pH is often much lower in acid mine drainage lakes and the concentration of dissolved substances much higher than in atmospherically acidified lakes.

Jurkovic and Robson (1981) are studying the effects on ammonifiers, denitrifiers, fungi and heterotrophic bacteria of a Sudbury area lake to reductions in pH to 4.1 in the laboratory. They observed no change in heterotroph levels, but noted a doubling in numbers of fungi, a twofold decrease in nitrogen cycle bacteria, and a significant change in respiration rate. Densities of nitrogen cycle bacteria were also reduced in the lake.

Microbial transformations of sulfur and nitrogen species may influence lake alkalinity (Brewer and Goldman 1976). Schindler (1980) recently suggested that increases in SO_4 concentrations will stimulate the sulfate-reducing bacteria in lakes that develop anoxic hypolimnia. The reduction of SO_4 has been used with success to renovate acid mine drainage waters. However, sulfate-reducing bacteria require anoxic conditions, and are stimulated by large quantities of organic matter, i.e., they prefer conditions typical of eutrophic lakes. The hypolimnia of most acid-susceptible lakes do not normally become anoxic, and could only be made anoxic by fertilization. Eutrophication is not a satisfactory trade-off for reducing acidity.

Effects on Amphibians

Because of the vulnerability of their habitat to pH depressions, amphibian populations are expected to be one of the earliest forms of wildlife to be affected by the acidification of fresh waters. Many species of frogs, toads, and salamanders breed in temporary pools. The pH of these pools may be very low during the spring as they are formed by a mixture of snowmelt water and spring rains. Temporary pools used as breeding sites by Jefferson (Ambystoma jeffersonianum) and yellow-spotted salamanders (A. maculatum) in New York were found to have hydrogen ion concentrations 1.5 pH units lower than nearby permanent ponds (Pough and Wilson 1977). Pough (1976) noted heavy embryonic mortalities and deformities in the yellow-spotted salamanders which breed in temporary meltwater ponds with pH less than 6.0. In central Ontario, Clark and Euler (1980) reported that the numbers of egg masses of yellow-spotted salamanders and male calling densities (an estimate of population size) of spring peepers (Hyla crucifer) were positively correlated with pH. This latter species often breeds in stream inflows and outflows or along the littoral zone of lakes, habitats also subjected to particularly heavy acid loads as a result of snow melt (Clark and Euler 1980). Strijbosch (1979) reported a negative correlation between pH and percentages of dead and moulded egg masses of frogs and toads in the Netherlands. The amphibian species of eastern Canada considered most susceptible to the effects of acidic deposition because of their breeding habitat are listed in Table 16.

The detrimental effects of acidity on adult amphibians have been shown in a number of field surveys. In England, Cooke and Frazer (1976) reported that no adult newts were caught from ponds of pH less than 3.8, while the natterjack toad (Bufo calamita) was not found below pH 5 (Beebee and Griffin 1977) in England. The common toad (Bufo bufo) did not occur where pH was less than 4.2, and the smooth newt (Triturus vulgaris) occurred only rarely at pH values less than 6.0. Hagstrom (1977) observed that the common toad and common frog (Rana temporaria) disappeared when pH levels reached 4.0-4.5. In new Hampshire, when a section of Hubbard Brook was artificially acidified to mean pH 4.0, salamanders disappeared from the study area (Hall and Likens 1980).

Laboratory experiments have demonstrated that reductions in pH are both directly and indirectly responsible for mortalities and deformities found during amphibian embryonic development. Gosner and Black (1957) studied the sensitivity of 11 species of frogs and toads to conditions of depressed [illegible] They found that the embryos were more sensitive than larvae or adults. In the case of the cricket frog (Acris gryllus) and northern spring peeper, an exposure of embryos to water in the vicinity of pH 4.0 for a few hours resulted in greater than 85 percent mortality. Beebee and Griffin (1977) noted abnormalities in natterjack toad spawn exposed to low pH and Noble (1979) observed delayed development and embryonic mortality at pH less than 4.75 in the leopard frog (Rana pipiens). In salamanders, the highest mortality of developing embryos occurs during neurulation, the late stages of gill development, and during hatching (Pough 1976, Pough and Wilson 1977).

Interspecific differences in embryonic tolerance to hydrogen ion concentration have been observed for the yellow-spotted salamander and Jefferson's salamander. Cook (1978) found no significant correlation between pond pH and percent embryonic mortality in either species, in six ponds with mean pH 5.6-5.3, whereas Pough (1976) found heavy embryonic mortalities and deformities in waters of pH less than 6.0. Egg transplant studies suggest that yellow-spotted salamander eggs from acidic ponds are more tolerant to acidity than eggs from neutral ponds (Nielsen et al. 1977). Anurans also exhibit variation in sensitivity. While Hagstrom

TABLE 16

SUSCEPTIBILITY OF BREEDING HABITAT TO pH DEPRESSION DUE TO ACIDIC DEPOSITION FOR THOSE AMPHIBIANS IN CANADA WHOSE RANGE OVERLAPS THE IMPACTED AREA

Potential for acidification of egg-laying habitat	Habitat	Species
high	meltwater pools	*Ambystoma maculatum* - Yellow-spotted salamander
		Ambystoma laterale - Blue-spotted salamander
		Ambystoma tremblayi - Tremblays salamander
		Bufo americanus - American toad
		Pseudacris triseriata - Chorus frog
		Rana sylvatica - Wood frog
		Rana pipiens - Northern leopard frog
		Hyla crucifer - Northern spring peeper
		Hyla versicolor - Gray tree frog
Moderate	permanent ponds	*Necturus maculosus* - Mudpuppy
		Notophthalmus viridescens - Red-spotted newt
		Bufo americanus - American toad
		Hyla versicolor - Gray tree frog
		Pseudacris triseriata - Chorus frog
		Rana catesbeiana - Bullfrog
		Rana clamitans - Green frog
		Rana pipiens - Northern leopard frog
		Rana septentrionalis - Mink frog
	streams	*Eurycea bislineata* - Northern two-lined salamander
		Necturus maculosus - Mudpuppy
	lakes	*Rana catesbeiana* - Bullfrog
low	bogs	*Hemidactylium scutatum* - Four-toed salamander
	logs and stumps	*Plethedon cinereus* - Red-backed salamander

From: Clark and Fischer (1981).

reported the elimination of the common toad at pH 4.5-4.0, Cooke (cited in Beebee and Griffin 1977) found this species in waters of pH 4.2 and noted that tadpoles were able to tolerate this hydrogen ion level.

It is likely that other factors influenced by the acidity of the water may be causing detrimental effects upon amphibian development. Huckabee et al. (1975) suggest that the combined effects of low pH and increased concentrations of aluminum, manganese and zinc may be the cause of the high mortality of shovel-nosed salamander larvae in Great Smoky Mountain National Park.

Because frogs, toads, and salamanders are important components of both aquatic and terrestrial ecosystems, reductions in the biomass of amphibians may have far reaching effects in both systems. Both salamanders and anurans are important contributors to the food web (DeBenedictis 1974, Burton and Likens 1975a,b, Cecil and Just 1979) and many birds and mammals depend heavily on these species for foods. Orser and Shure (1972) reported that amphibians are one of the top carnivores in temporary ponds and small streams and are important predators of aquatic insects. In turn, they serve as a high protein food source for other wildlife (Burton and Likens 1975a,b).

Given the sensitivity of amphibians to depressed pH, it is inevitable that those species inhabiting temporary pools in acid-sensitive regions will suffer severe decreases in density, and may become locally extinct in parts of the Precambrian shield. The ranges of some species of amphibians in eastern North America are restricted almost entirely to areas presently receiving high levels of acidic deposition (Table 16). However, elimination of these species may allow other species to expand due to decreased competition.

Effects of Low pH on Fish

The purpose of this section is to briefly review how fish respond to increasingly acidic environments. For more comprehensive treatments of this subject, the reader is referred to reviews by Fromm (1980) and, especially, Spry et al. (1981). There is extensive literature available on laboratory studies (see Doudoroff and Katz 1950, and EIFAC 1969) designed to elucidate mechanisms of pH toxicity. These laboratory results are reviewed, as they are useful in explaining field observations and suggesting new field studies.

Results from laboratory experiments demonstrate how overall water quality (i.e., hardness, ionic strength) can affect pH toxicity. For example, as ionic strength and water hardness increase, the short-term sensitivity of fish to waters of pH 4 is decreased (reviewed in Spry et al. 1981). The ameliorative effects of high Ca and ionic strength appear most beneficial to early larval stages at intermediate pH, ~5. This is consistent with field observations that in more dilute water fish communities disappear at higher pH (Leivestad and Muniz 1976) due to recruitment failure (Harvey 1979). In addition to hardness and ionic strength, survival of fish in water of low pH is influenced by the type of acid present (Packer and Dunson 1972, Swartz et al. 1978), temperature (Kwain 1975, Robinson et al. 1976), the level of dissolved carbon dioxide in the water (Neville 1979), and by the presence of metals (Swartz et al. 1978, Baker and Schofield 1980).

Field evidence suggests that the susceptibility to low pH appears to be species specific. From his studies of La Cloche Mountain lakes, Beamish (1976) estimated the pH at which reproduction ceased in 11 species (Table 17).

Some species of fish have been reported to have a seasonal response to low pH (Lloyd and Jordan 1964, Falk and Dunson 1977). As well as interspecific differences in sensitivity, variability in the sensitivity of different strains of the same species has also been observed (Robinson et al. 1976, Swartz et al. 1978). However, it is probable that the acidification of lakes and rivers in North America is proceeding too rapidly to enable genetic selection for acid tolerant strains to occur naturally, on a wide scale (Schofield 1976).

Results of laboratory studies have demonstrated that some species of fish are particularly sensitive to low pH in certain reproductive stages (reviewed by Spry et al. 1981). Low pH can inhibit gonadal development (Ruby et al. 1977, 1978), reduce egg production (Mount 1973, Craig and Baksi 1977), affect egg and sperm viability (Menendez 1976, EIFAC 1969) and inhibit the spawning act (Menendez 1976, Craig and Baksi 1977). Embryonic development may be affected by low pH (Trojnar 1977, Swartz et al. 1978) and low environmental pH can affect egg internal pH (Daye and Garside 1980a). Generally, fry appear less resistant to low pH than eggs (Spry et al. 1981). Consequently fry may be particularly vulnerable to low pH conditions associated with spring melt and storm events.

In the field, there have been several reports of fish kills apparently related to the acidification of rivers and lakes. In Scandinavia, for example, Jensen and Snekvik (1972) reported mass mortality of Atlantic salmon (Salmo salar), and Leivestad and Muniz (1976) reported a brown trout (Salmo trutta) kill. Both fish kills have been correlated with reduced water pH.

In North America, Harvey (1979) reported a kill of several species, primarily pumpkinseeds (Lepomis gibbosus) in Plastic Lake, Ontario, during spring snow melt. Surface water pH was 5.5 while the pH of the major inlet stream was 3.8. During the spring of 1981 some in situ bioassays were conducted in Plastic Lake (Harvey 1981). Rainbow trout, Salmo gairdneri, were placed in cages at four locations in Plastic Lake and at four locations in the control, Beech Lake. At each location three non-metal cages of 35 fish were situated. No mortality occurred at any of the cage sites in the control (pH 6.09-7.34, alkalinity 132-390 μeq/ℓ). In Plastic Lake, however, mortality ranged from 12% at the lake outlet (pH: 5.0-5.85) to 100% at the inlet (pH: 4.03-4.09). Although aluminum concentrations were not measured at the time of the 1979 fish kill and aluminum data for 1981 is not yet available, total aluminum concentrations in Plastic Lake during the 1979 and 1980 ice-free season varied between 9 and 30 μg/ℓ in the lake, and between 240 and 490 μg/ℓ in the major inlet.

In reviewing caging studies it is important to note that in natural situations, fish have been reported to avoid areas of adverse water quality (Muniz and Leivestad 1980), a behavioral response prevented by

TABLE 17

APPROXIMATE pH AT WHICH FISH IN THE
LA CLOCHE MOUNTAIN LAKES STOPPED REPRODUCTION

pH	Species	Family
6.0 to 5.5	Smallmouth bass *Micropterus dolomieui*	Centrarchidae
	Walleye *Stizostedion vitreum*	Percidae
	Burbot *Lota lota*	Gadidae
5.5 to 5.2	Lake Trout *Salvelinus namaycush*	Salmonidae
	Troutperch *Percopsis omiscomaycus*	Percopsidae
5.2 to 4.7	Brown bullhead *Ictalurus nebulosus*	Ictaluridae
	White sucker *Catostomus commersoni*	Catostomidae
	Rock Bass *Ambloplites rupestris*	Centrarchidae
4.7 to 4.5	Lake Herring *Coregonus artedii*	Salmonidae
	Yellow perch *Perca flavescens*	Percidae
	Lake chub *Couesius plumbeus*	Cyprinidae

From: Beamish (1976).

containment. However, avoidance may not be possible for some less mobile life stages or in situations where most of the waterbody is impacted. In Plastic Lake the caging studies supplement field observations. Shortly after the caging studies (April 24, 1981), SCUBA divers observed dead pumpkinseeds and rainbow smelt, Osmirus mordax, in Plastic Lake (Harvey 1981).

One mechanism which appears to contribute to species extinction in acidified systems is the failure of recruitment of year-classes. In a study of 38 La Cloche Mountain lakes, Ryan and Harvey (1980) reported evidence of recruitment failure in the yellow perch (Perca flavescens) populations of the two lakes of lowest pH, Patten Lake (pH 4.1) and Terry Lake (pH 4.3). The age group composition of yellow perch in Patten Lake is illustrated in Figure 39. Ryan and Harvey (1980) also found evidence of reduced and missing year classes of young fish in five populations of rock bass (Ambloplites rupestris) in acid-stressed La Cloche lakes. The absence of older fish in populations in acid-stressed lakes has also been reported (Beamish et al. 1975, Ryan and Harvey 1980, Harvey 1980). This effect is illustrated by the age composition of white suckers in George Lake, Ontario, (Figure 40) in the time period from 1967 to 1979. Rosseland et al. (1980) also reported the absence of post-spawning age perch and brown trout in three lakes within the Tovdal River System, Norway. The predominance of young fish occurred after a fish kill in 1975.

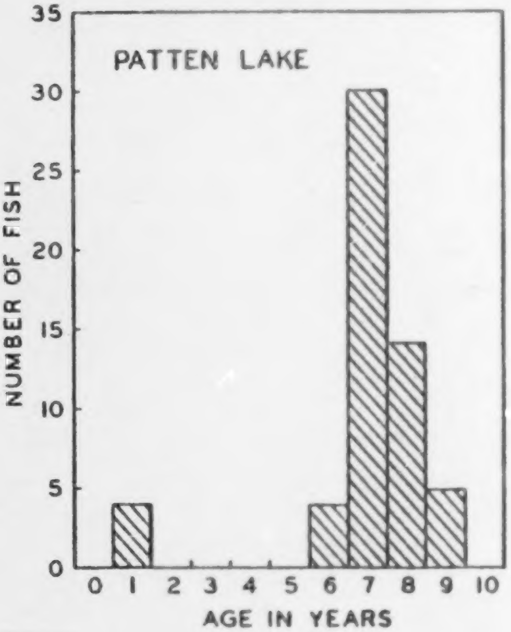


Figure 39. Age composition of yellow perch (Perca flavescens) captured in Patten Lake, Ontario, pH 4.1 (Ryan and Harvey 1980).

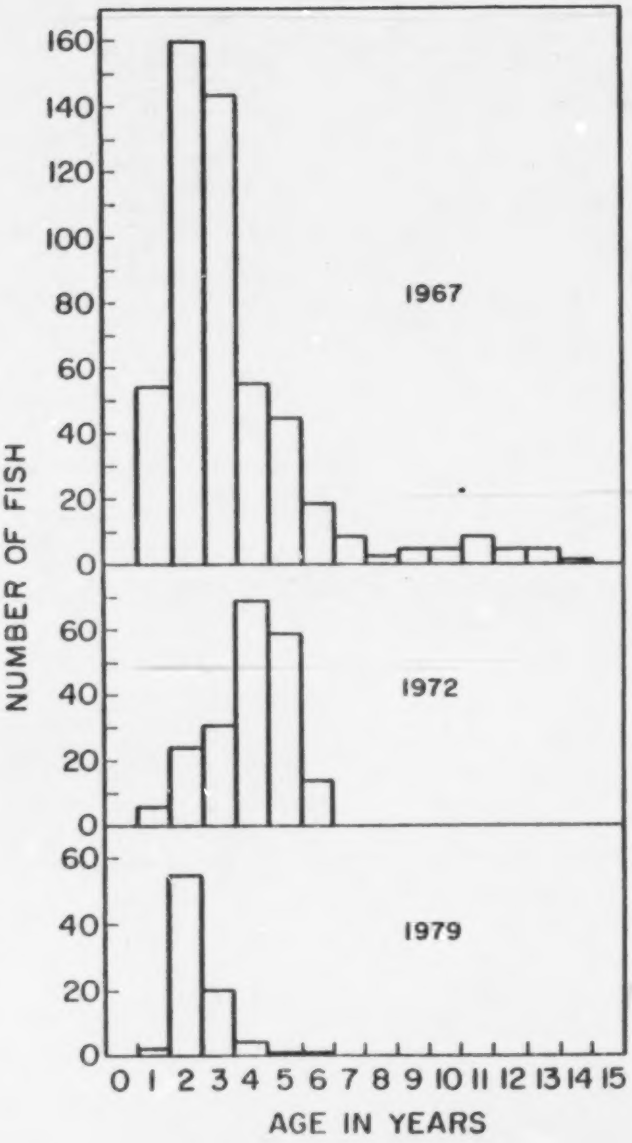


Figure 40. Changes in the age composition of the white sucker, *Catostomus commersoni*, in George Lake, Ontario. (Harvey *et al.* 1981.)

Recruitment failure and the loss of older fish from a population can be a natural occurrence as well as a response to a variety of factors. In the examples cited, water chemistry data suggest these phenomena are correlated with acidification of the waterbodies. However, to conclusively attribute the symptoms to acidification, one would have to build a comprehensive case history of the system, including measures of temperature, exploitation rate, water level fluctuations, etc., as well as natural variability in age class strength.

Studies of Aluminum Effects on Fish

Concentrations of metals can be elevated in acid-stressed lakes (Beamish 1974, Scheider et al. 1979) because of increased atmospheric deposition, increased mobilization from the sediments and/or mobilization from the watershed. Probably the most important consequence of acidification is the mobilization of aluminum from the watershed to the aquatic environment (Scheider et al. 1979, Cronan and Schofield 1979). Elevated levels of aluminum in waters affected by acidification have serious effects on fish within the pH range normally considered harmful to aquatic biota (Baker and Schofield 1980).

The chemistry of aqueous solutions of aluminum is complex. A simplified description of the relevant chemistry is contained in Spry et al. (1981). The solubility of aluminum is minimal at pH 5.5, increasing as pH increases or decreases. At pH greater than 5.5, soluble aluminum is mostly anionic; at pH less than 5.5 it exists increasingly as a cation. The solubility of aluminum is apparently regulated by some form of aluminum trihydroxide solid, $AL(OH)_3(s)$, which is minimally soluble at pH 5.6-6.0 (Driscoll 1980). Fewer hydroxyl ligands at lower pH allow the aluminum to become cationic, eventually becoming Al^{3+} at pH less than 5. Cationic aluminum is able to form complexes with a number of ligands, including soluble organics and fluorides, which can decrease its toxicity (Figure 41) (Baker and Schofield 1980, Driscoll et al. 1980).

Laboratory studies on the survival of brook trout (Salvelinus fontinalis) have shown reduction to less than 40% after 14 days (Figure 41) at aluminum concentrations of 420 and 480 μg/ℓ and pH levels of 5.2 and 4.4, respectively (Driscoll et al. 1980). Baker and Schofield (1980) found that the sensitivity of brook trout to elevated aluminum increased with age. They also found that the presence of aluminum actually mitigated the toxic effects of low pH to fish eggs. The survival of brook trout and white sucker embryos through the eyed stage at pH levels below 5 was significantly better in treatments with aluminum than without. After hatching, brook trout fry were more susceptible to aluminum at the extremes of the pH range tested (4.2 to 5.5) than at intermediate pH levels (Figure 42). The greater susceptibility of fry at these extreme pH's is due to a dual mechanism of aluminum toxicity. At low pH, aluminum (probably $Al^{3}+$) appears to cause osmoregulatory stress and loss of salts from blood plasma. At the higher pH, precipitation of $Al(OH)_3(s)$ damages the gills and leads to clogging by mucous (Baker, personal communication). Baker and Schofield (1980) also found that at all stages white suckers were substantially more sensitive to low pH levels and elevated aluminum concentrations than brook trout.

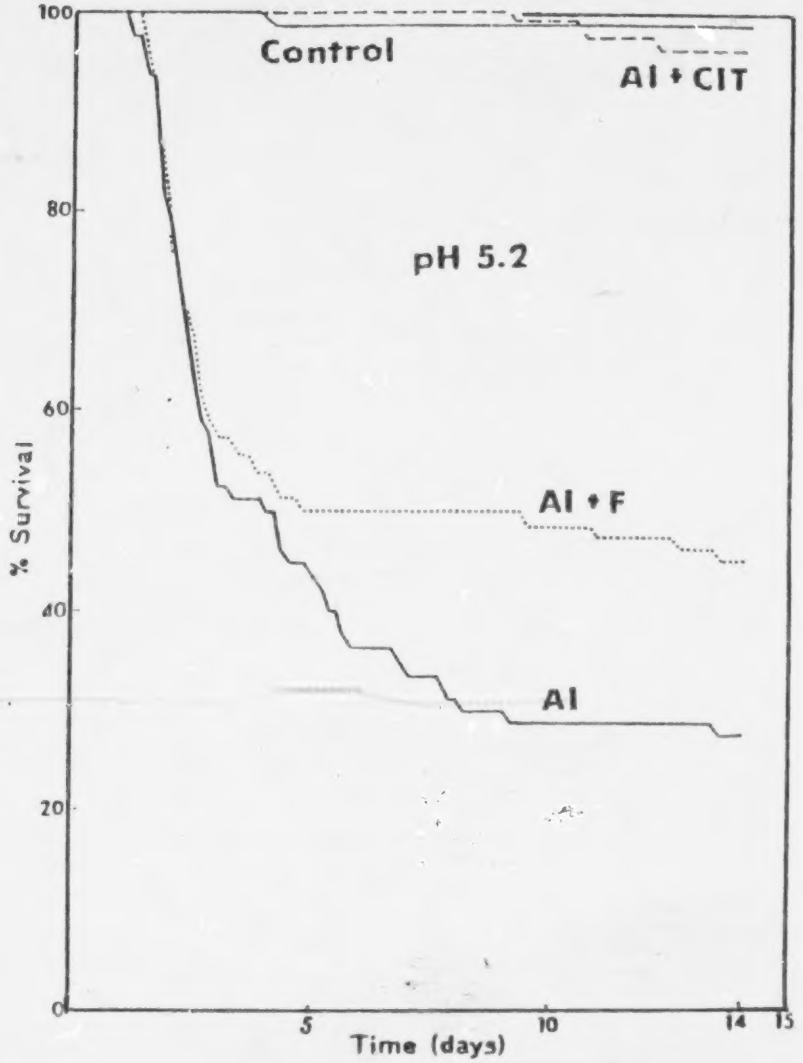


Figure 41. Mean percent survival of brook trout fry plotted as a function of time at pH 5.2 with no aluminum (control), with 0.5 mg Al added per liter, with 0.5 mg Al/liter complexed with fluoride, and with 0.5 mg Al/liter complexed with citrate (ST 9) (Baker 1981, personal communication).

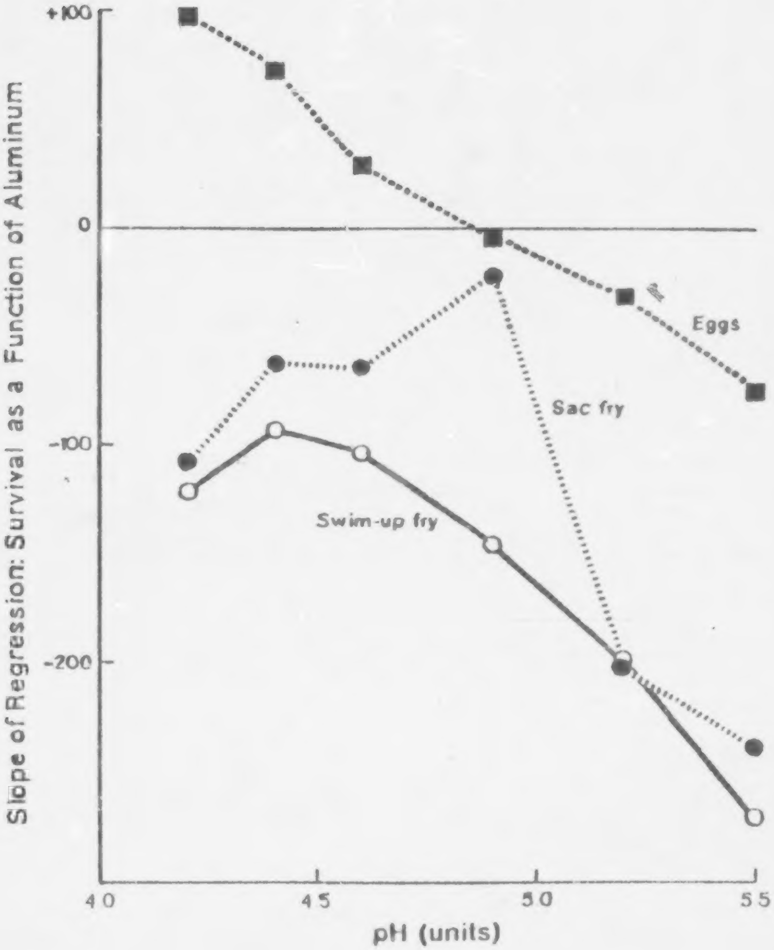


Figure 42. Slope of regression of brook trout survival (% hatching of eggs, 14 day % survival of sac fry and fry) as a function of aluminum concentration plotted as a function of pH level (Baker 1981, personal communication).

Schofield and Trojnar (1980) indicated that levels of aluminum, rather than pH alone, may be the primary factor limiting survival of brook trout stocked in acidified Adirondack lakes. Muniz and Leivestad (1980) and Schofield and Trojnar (1980) suggest that mass mortalities of fish, observed during transient episodes of acidification in the spring, are most likely a result of elevated concentrations of inorganic aluminum, mobilized from the soils by strong acids present in snowmelt water. The former study demonstrated that pH depression alone (to levels of pH 4.7-5.0) did not induce physiological stress to fish, as determined from changes in plasma chloride levels. However, associated increases in aluminum to 0.2 mg/ℓ or more were found to be sufficient to induce severe stress and eventual mortality.

Aluminum levels in streams in the Great Smoky Mountains National Park, U.S.A. (Hermann and Baron 1980), and in the Muskoka-Haliburton area of Ontario (total aluminum levels from 1976 to mid 1978 ranged between 5 and 1000 μg/ℓ in 60 streams) do fall within the ranges demonstrated to be lethal to fish in laboratory conditions.

However, as the laboratory studies demonstrate, the evaluation of aluminum as a toxic element in acidified waters is not a simple function of total concentrations. In evaluating the survival of indigenous fish populations one must consider the form of aluminum, the level of hydrogen ion, and the fish species present and their life history stage.

Impacts on Fisheries in Canada and the United States

Adirondacks. The Adirondack region is one of the largest sensitive lake districts in the eastern United States, and it is also the most heavily impacted by acidic deposition. A recent inventory of Adirondack waters, classified by type of fishery supported, indicates that the brook trout fishery has been most severely affected by acidification (Pfeiffer and Festa 1980). These authors have shown that at least 180 former Adirondack brook trout ponds will no longer support populations because of acidification. Currently, 212 Adirondack lakes have a pH <5.0, and an additional 256 lakes have a pH between 5.0 and 6.0. A survey of 214 high elevation lakes in 1975 by Schofield (1976) revealed that 52 percent had surface pH levels below 5.0, and 90 percent of these acidified lakes were devoid of fish life (Table 18). These lakes are very sensitive to acidification. Comparable data collected for 40 of these lakes, from the period 1929 to 1937, indicated that only four percent were below 5.0 and devoid of fish (Figure 43). Entire fish communities, consisting of brook trout, lake trout, white sucker, brown bullhead and several cyprinid species, were eliminated over the forty year period, in association with decreased pH. The number of fish species represented in these high elevation lakes was also observed to decline markedly below pH 5.5.

Ontario. More data on inland fisheries resource impacts from lake acidification are available from Ontario than from any other province in Canada. The case study of lakes in the La Cloche Mountain range by Beamish and Harvey (1972) is best known. These lakes have a naturally low buffering capacity and are only 65 km southwest of the Sudbury area smelters.

TABLE 18
DISTRIBUTION AND FREQUENCY OF OCCURRENCE OF FISH SPECIES COLLECTED DURING
SURVEYS OF ADIRONDACKS LAKES >610 METERS ELEVATION
NUMBERS IN ( ) REFER TO EXTINCT POPULATIONS

pH	<4.5	4.5-4.99	5.0-5.49	5.5-5.99	6.0-6.49	6.5-6.99	>7.0	TOTAL
Total lakes	16	95	36	15	28	22	3	215
% of total	7.1	44.2	16.7	7.0	13.0	10.2	1.4	
No fish	16	74	2	1	0	0	0	93
%	17.2	79.6	2.1	1.1				
Fish	0	20	25	11	22	19	3	100
%		20.0	25.0	11.0	22.0	19.0	3.0	
Brook trout	0	16(26)	18(1)	11	17	17	3	82
%		19.5	21.9	13.4	20.7	20.7	3.7	
f	.80	.72	1.00	.77	.89	1.00		
Lake trout	0	0(5)	1(2)	4	2	4	2	13
%			7.7	30.8	15.4	30.8	15.4	
f			0.4	.36	.09	.21	.67	
Bullhead	0	8(8)	11(1)	5	14	9	3	50
%		16.0	22.0	10.0	28.0	18.0	6.0	
f		.40	.44	.45	.64	.47	1.00	
White sucker	0	3(1)	7(1)	8	7	8	3	36
%		8.3	19.4	22.2	19.4	22.2	8.3	
f	.15	.28	.73	.32	.42	1.00		
Creek chub	0	0(7)	5	7	5(1)	8	2	27
%			18.5	25.9	18.5	29.6	7.4	
f			.20	.64	.23	.42	.67	
Golden shiner	0	3(4)	3	1	8	3	2	20
%	15.0	15.0	5.0	40.0	15.0	10.0		
f	.15	.12	.09	.36	.16	.67		
Common shiner	0	9(2)	0(1)	3(1)	1	3	3	11
%		9.1	0	27.3	9.1	27.3	27.3	
f		.05		.27	.05	.16	1.00	
Lake chub	0	1(1)	0	2	0	1	3	7
%		14.3		28.6		14.3	42.9	
f		.05		.18		.05	1.00	
Redbreast sunfish	0	0	0	0	0	3	0	3
%						100.0		
f						.16		
Common sunfish	0	0(1)	0	1	1	2	2	6
%				16.7	16.7	66.7	66.7	
f				.09	.05	.11	.67	

From: Schofield (1976).

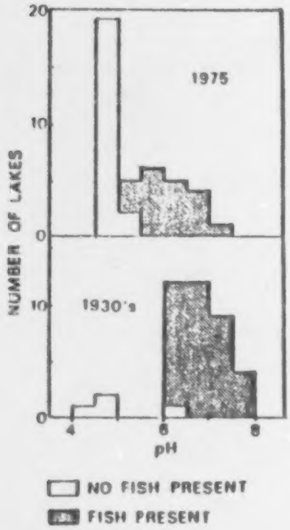


Figure 43. Frequency distribution of pH and fish population status for 40 high elevation lakes surveyed in the 1930s and again in 1975 (Schofield 1976).

Some of the lakes appeared to have already lost fish populations at the time of the first survey, 1965-66; others had populations that were endangered, and still others were apparently in a healthy condition (Beamish 1976). The fish community of Lumsden Lake (one of 68 examined) has been studied for 14 years. The following chronology of fisheries losses has been assembled by Harvey (1980) from his studies with Beamish (Beamish and Harvey 1972), from Provincial Government capture records dating to the early 1960's, and from observations by local anglers and residents for some species prior to 1960:

1950's - 8 species present

1960 - last reported capture, yellow perch, Perca flavescens and burbot, Lota lota

1960-65 - sport fishery fails (pH 6.8, Sept. 1961)

1967 - last capture of lake trout, Salvelinus namaycush and slimy sculpin, Cottus cognatus

1968 - tagged population of white sucker, *Catostomus commersoni* disappears

1969 - last capture of trout perch, *Percopis omiscomaycus* and lake herring, *Coregonus artedii*

1971 - last capture of lake chub, *Couesius plumbeus* (pH 4.4, Aug. 1971)

The age distribution of a population of white suckers in Crosson Lake (Muskoka-Haliburton area of Ontario) was examined by Harvey (1980). The population in Crosson Lake (pH 5.1) showed a truncated age composition (Figure 44) compared with the populations in less acidic Red Chalk (pH 6.3) and Harp Lakes (pH 6.3). A similar loss of older fish from the white sucker population in George Lake (Harvey 1980) has been discussed previously as a symptom of acid stress.

Quebec. Quebec has large numbers of lakes which are potentially sensitive to acidic inputs, but comprehensive fisheries data that might substantiate this view are unavailable at this time. Recently Charette and Lagacé (1981, unpublished manuscript) have shown that angling success in the Laurentide Park, north of Quebec City, has decreased approximately 30% between 1970 and 1978. The reduction is not attributed to overfishing, as the mean weight of the catch has remained constant. The analyses on the 63 lakes for which there is pH and angling data showed that watersheds having the lowest mean lake acidity contained a higher frequency of lakes having abnormally low angling success.

Nova Scotia. There are 37 rivers flowing through Nova Scotia for which there are records to verify that they are, or once were, Atlantic salmon rivers. For 27 of these rivers, almost complete angling catch records are available (annual reports from Federal Fishery Officers) from 1936. Of these 27 rivers, 5 have undergone major salmon stock alterations since 1936 by dam construction/removal and extensive hatchery stocking, or both. To examine the impact of acidification on angling success, the 22 remaining rivers were divided into two groups based on 1980 pH levels: ten of the rivers are presently at pH <5.0 and 12 are at pH >5.0.

For the 12 rivers presently at pH >5.0: one shows a statistically significant decline in angling success since 1936, another shows a significant increase, and ten show no significant trend. Of the ten rivers with pH's <5.0, 9 show significant declines, and one shows no significant trend.

To combine the data so as to form averages for the two groups, the records were first normalized by expressing each river's angling catch as a percentage of the average catch during the first five years of record (1936-40). These percentages were than summed and averaged for each of the two pH groups. The results (Figure 45) reveal virtually identical angling catches in the two groups until the early 1950s; after which the angling catches in rivers of pH <5 went into a decline, while the rivers of pH >5 continued to show no significant trend. Many factors other than

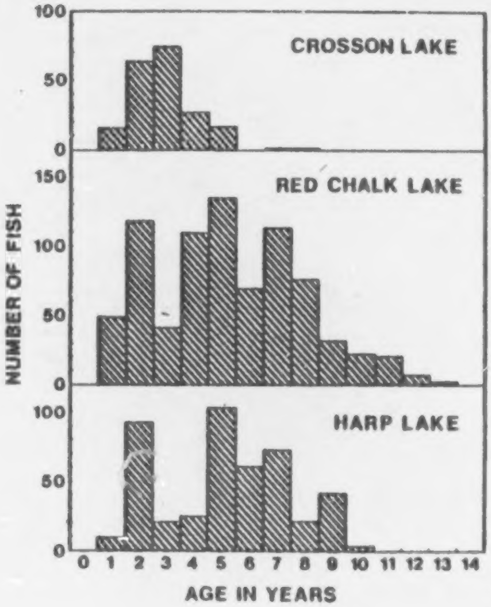


Figure 44. Age Composition of the White Sucker population of three lakes in the Muskoka-Haliburton Region of Ontario (from Harvey 1980).

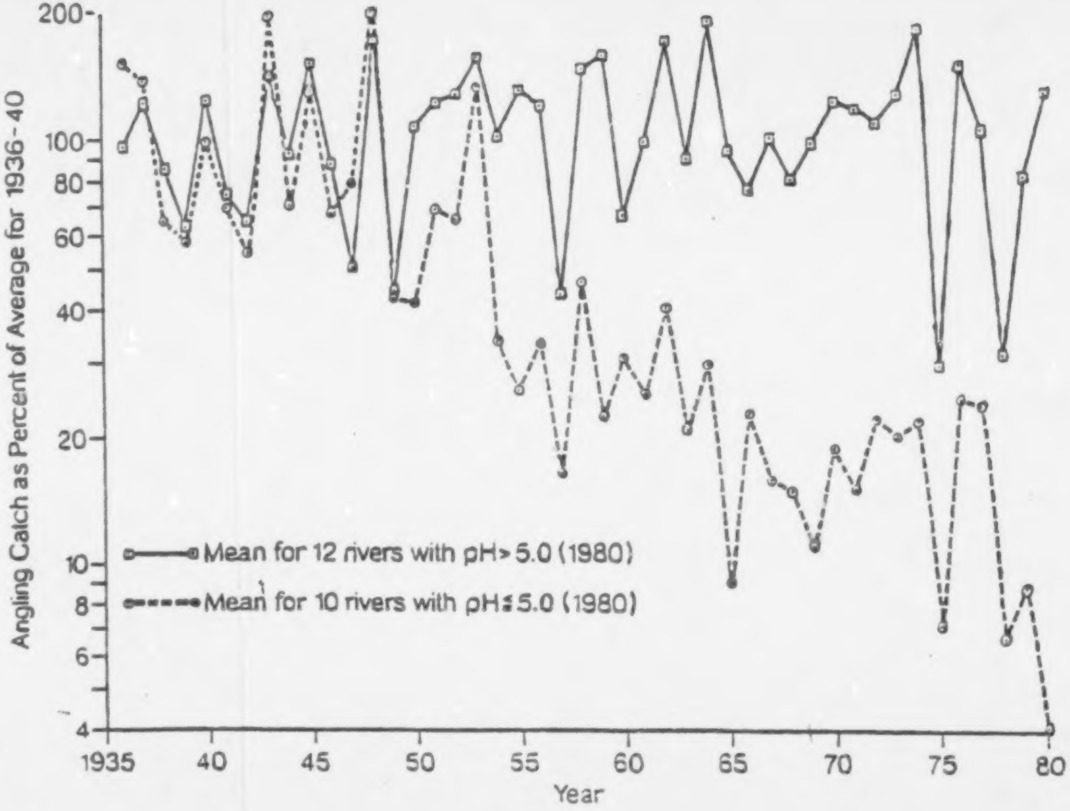


Figure 45. Average angling success for Atlantic Salmon in 22 Nova Scotia rivers since 1936. (W. Watt, unpublished manuscript 1981).

pH (e.g., stream flows and sea survivals) also affect the angling record, but the variation from these other factors affects both groups identically. The only difference is that the angling success in rivers of pH <5 has declined since 1950 while in rivers of pH >5, it has, on average, remained the same.

There are historical water chemistry data for some of these affected rivers (Thomas 1960) from surveys performed in 1954 and 1955. In the past 25 years, the pH of the Tusket River has decreased from an annual range of 4.9-6.1 to 4.6-4.9; the Roseway from a range of 4.4-6.4 to 4.3-4.5; the Jordan River from about 5.1 to a range of 4.4-4.6; the Medway River from a range of 5.5-6.5 to 5.1-5.8; and the Clyde River has decreased from 5.0 to 4.6. Alkalinity was not detectable in the Tusket, Clyde, Roseway and Jordan rivers in 1979-80, but was measurable during Thomas' study 25 years earlier. Although Thomas (1960) sampled some of these rivers only once, his water quality data suggest that salmon reproduction in a few rivers may have been adversely affected due to acidity by the early 1950's. Even to the casual observer, some of the affected streams are strikingly different in appearance from streams with mean annual pH's above 5.0. When they were recently surveyed, in the latter part of the summer, affected stream bottoms were covered with dense mats of filamentous algae and Sphagnum moss had invaded the stream channel in some areas (R. H. Peterson, personal communication).

Within Nova Scotia, the distribution of acid water bodies is well correlated with geology (Watt 1981). Seasonal variation in the pH of acidified rivers is about 0.5 unit, with the annual minimum occurring in mid-winter and a maximum in late summer. Historical data indicate that the local rate of acidification has been of the order of 0.3-0.4 pH units in 20 years (see previous sections). At present there are 9 rivers with pH 4.7 which previously had salmon but now have no salmon or trout reproduction; 11 rivers are in the pH range 4.7-5.0, where some juvenile salmon mortality is probably occurring; and 7 rivers are in the pH range 5.1-5.3, which is considered borderline for Atlantic salmon (Figure 46). The acidification threat to these 27 rivers represents only 2 percent of the total Canadian habitat potential for Atlantic salmon, but in Nova Scotia it represents 30 percent of the available salmon potential.

One of the Nova Scotia rivers "threatened" by increased inputs of acidic deposition, the Mersey, contains an Atlantic salmon hatchery. The Mersey watershed has poorly developed soils, and its underlying geology is Devonian granite. The mean total alkalinity of samples collected from the river in 1978-79 was always less than 0.5 mg/ℓ, while mean pH was 5.2 with a range of 4.9-5.4. In 1954-56 the river had a mean pH of 5.8, with a range of 5.4-6.6, and a mean total alkalinity of 2.4, with a range from 1.0-4.4 (Thomas 1960). Mean sulfate values have been estimated to have increased from 1.6 mg/ℓ in 1954-55 to 3.3 mg/ℓ in 1978-79. These data suggest that the river is sensitive to, and has been affected by, atmospheric inputs.

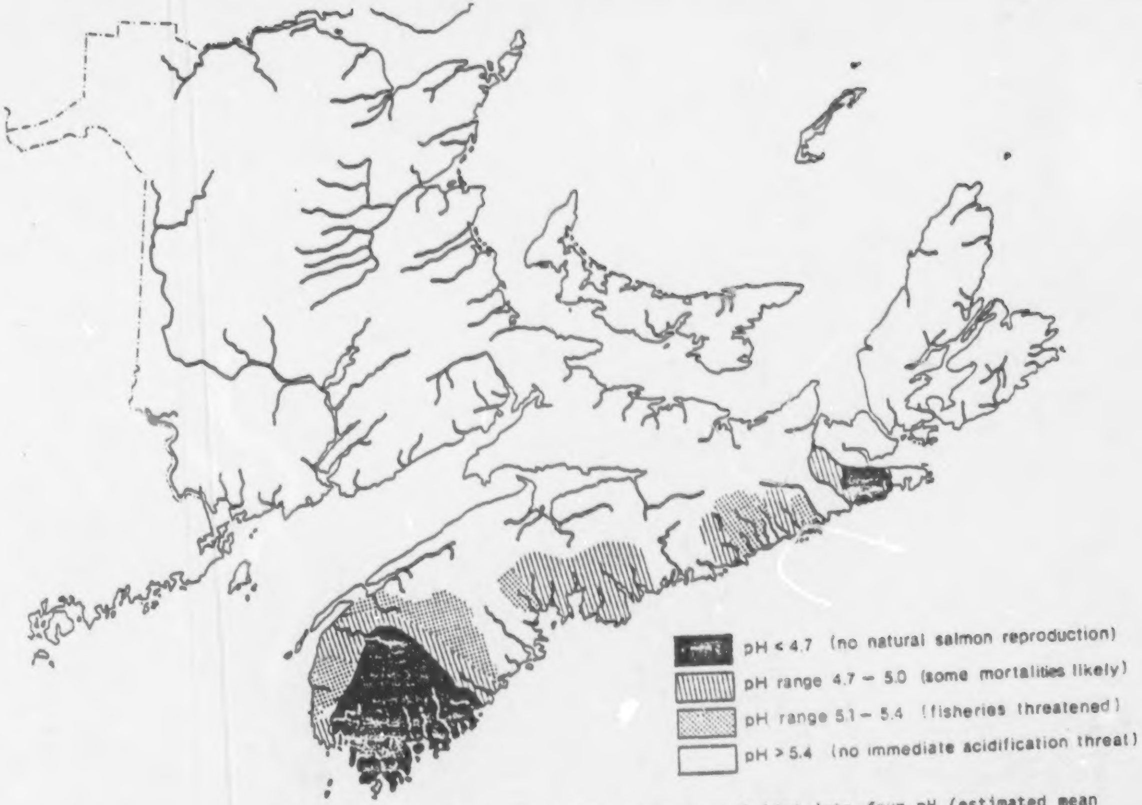

pH < 4.7 (no natural salmon reproduction)
pH range 4.7 – 5.0 (some mortalities likely)
pH range 5.1 – 5.4 (fisheries threatened)
pH > 5.4 (no immediate acidification threat)

Figure 46. The Atlantic salmon rivers of the Maritimes have been divided into four pH (estimated mean annual) categories based on significance to salmon reproduction. Present evidence indicates that salmon cannot reproduce at pH's below 4.7. Juvenile mortalities of 30% or more are expected in the pH range 4.0-4.7. Rivers in pH range 5.1-5.4 are considered threatened. Above pH 5.4 there is no immediate acidification concern with regard to Atlantic salmon (Watt 1981).

During the period 1975-78, mortality of Atlantic salmon parr reared at the Mersey hatchery typically occurred during the 3rd and 4th weeks after first feeding. This higher-than-expected mortality was attributed to increased acidity in spring river water supplying the hatchery. In 1979, by treating the water with $CaCO_3$, the salmon fry mortality was reduced from 30 percent to 3 percent (Farmer _et al_. 1980). In 1980 the water was again treated and produced the same dramatic increase in survival of parr.

Hendrey and Wright (1976) report that "acid precipitation has devastated the salmonoid fish in southern Norway." Massive fish kills of adult salmon and trout have been reported in their river systems, usually occurring during the spring snowmelt or after heavy autumn rains. An intensive survey of 50 lakes in southern Sweden showed that inland freshwater species are also threatened. The decreases in pH have resulted in the elimination of Atlantic salmon from many Norwegian rivers in the past 20 years. Scandinavian scientists have concluded that, directly or indirectly, the principal cause of the fish losses is acidification of the waters due to acidic deposition. If current acid loadings continue, it is possible that more of the inland and Atlantic salmon fisheries in Canada will be lost. Portions of Canada's fishery resource appear to be responding in the same way as the fish stocks in Norway and Sweden.

Loss of Genetically Unique Fish Stocks

Loss of fish from lakes and rivers appears to be an irreversible process. Over several thousand generations, most species appear to have evolved discrete stocks adapted to similar, yet discrete and specific, habitats (Loftus 1976). The basic unit of a stock is the gene pool, which is composed of a naturally sustained, genetically variable group of individuals, adapted through evolution to local environmental conditions. Man-induced stresses (i.e., cultural eutrophication, habitat destruction, over-exploitation, species introduction and contaminants) have, separately and synergistically, reduced this genetic variability in populations of native fishes. Surface water acidification is an example of such a stress. Beamish and Harvey (1972) documented the loss of gene pools of fish in acidified lakes in Ontario. The Ontario Ministry of Natural Resources has attributed the extinction of lake trout (_Salvelinus namaycush_) in 27 lakes in the Sudbury-Temagami area to acidification (C. Olver, personal communication).

As the extinction of species has increased with the tempo of human activities, it is likely that the rate of loss of genetically discrete, locally adapted stocks has been many times greater. A naturally evolved complex of stocks appears essential to fully utilize the productive capacity of waters. Therefore, it is important to recognize and preserve stocks (Loftus 1976). Fisheries managers are now using the stock concept to allocate harvest and rehabilitate fish populations (Ricker 1972). Continued loss of discrete stocks may inhibit effective re-establishment of naturally reproducing populations in waters undergoing rehabilitation. The ramifications of these losses affect fisheries management specifically, and society in general. Genetic variability is a biological resource that must be managed (Ryman and Stahl 1981) or future opportunities for economic and recreational use of this resource will be jeopardized.

Mercury in Fish

Because elemental mercury can exist in the gas phase at ordinary air temperatures, it is ubiquitous in the environment. Large quantities of mercury pass between the earth and the atmosphere by natural cycling processes which have been going on for millions of years. Therefore, the mere presence of mercury in any compartment of the environment does not necessarily imply any human influence. However, a considerable body of evidence exists that implicates human beings as a current major factor in the global dispersion of mercury. A recent National Academy of Science report (NAS 1978) presents evidence that human activities have, on a global scale, increased mercury emissions to the atmosphere by about 25 to 30% when compared to natural emissions rates. Much of this (~ 40%) comes from the burning of fossil fuels and ore mining activities. The intention of the U.S. to increase coal consumption by the end of this century will further increase atmospheric emissions. Coal contains, on the average, about 200 µg/g of mercury, and most of this (~97%) is emitted from stacks upon combustion (Billings and Mattson 1972). The mean residence time of mercury in the atmosphere is not accurately known but is probably in the order of several weeks to months (NAS 1978). This is ample time for long-range transport prior to deposition. These points may be of particular concern regarding any policy which embraces increased use of coal in its policy options. If all other factors were equal, one could expect such large increases in atmospheric emissions to increase the deposition rate and, hence, the concentrations of mercury in living organisms. However, increased deposition has not yet been fully substantiated as atmospheric studies on mercury have been carried out only in a preliminary way to date.

While no data base presently exists which explicitly shows increased atmospheric mercury deposition to biologically sensitive lakes, there is substantial evidence of the impact of pH on mercury content in fish (Lander and Larsson 1972, Brouzes et al 1977, Hakanson 1980). Bisogni and Lawrence (1973) and Jernelov et al. (1976) have argued that one reason fish in waters of low pH contain more methylmercury than fish in waters of comparable mercury contamination, but higher pH, seems to be that acidic waters must be able to retain the monomethyl-form of mercury in solution. The main form of akly1 mercury in neutral to slightly alkaline waters is dimethylmercury, which is volatile and quite insoluble in water. Consequently, low pH waters would contain more mercury in monomethyl form, which in turn would increase the probability of the element being assimilated by fish. It is, however, important to recognize that pH is not the only variable which determines the mercury load in fish. Other factors include mercury availability, level of bioproduction (i.e., lake trophic state), lake flushing rates and lake/watershed drainage area ratio (Hakanson 1980).

Few data exist to link mercury concentrations in fish to lake acidification. However, an increase in concentrations of mercury in fish from

1970 to 1978 is evident in some lakes in the Adirondack Mountains (C. L. Schofield, personal communication). In Ontario, Suns et al. (1980) have been sampling young-of-the-year and yearling fish for contaminant studies. Their data (Figure 47) demonstrates increased mercury concentrations with decreasing pH in lakes in the Haliburton area. For lakes with similar pH, the mercury was higher in fish from lakes with a higher ratio of drainage area/lake volume. This result implies that a quantity of mercury from either direct atmospheric deposition, or from watershed leaching, is influencing the fish concentrations. In 1980, the survey was extended to include adult bass, which are important to the sport fishery. Bass from six of the nine lakes studied had average mercury concentrations above the Canadian guideline for unlimited human consumption of 500 ng/g, and, in one lake, exceeded the U.S. guidelines of 1000 ng/g (K. Suns, personal communication).

Effects of Acidic Deposition on Birds and Mammals

Only a few reports have attempted to relate acidification to changes in avian or mammalian populations. In a review paper, Almer et al. (1978) reported that, "fish-eating birds, such as mergansers and loons, have been forced to migrate from several acid lakes, with decreasing fish stocks, to new lakes with ample food supply. In this way, many territories will become vacant, and this will lead to decreasing stocks." The extent of the problem in Sweden has not been documented at this time. In another Swedish study, Nilsson and Nilsson (1978) found a positive correlation between pH and "water" bird species diversity. "Water" birds were defined as those species dependent upon open water, and included a loon species, and several waterfowl and gull species. They also suggested that a reduction in young fish, a very important food source for aquatic birds, may lead to low reproductive success and local extinction in some bird species. Eriksson et al. (1980) also proposed that reduced reproduction of fish may decrease the availability of fish of the sizes appropriate to young diving water birds.

In North America, the only information on changes in aquatic bird populations comes from New York's Adirondack Mountains and relates to the Common Loon (*Gavia immer*). Loon nesting densities have declined over the past 15 years (McIntyre and Manas 1979, Trivelpiece et al. 1979). During the same time fish populations in this area have also declined (Schofield 1976). To date, however, changes in loon populations in the Adirondacks have been interpreted only with respect to human disturbance, and the probable role of food depletion has not been investigated.

Effects of acidic deposition on wildlife may also be occurring as a result of increased solubility and availability of metals in acidified lakes (Suns et al. 1980, Schofield 1980). Eriksson et al. (1980) suggested this as a cause of the high mercury levels in Common Goldeneye eggs in areas of Sweden with acidified water but no industrial deposition. Studies by Nyholm and Myhrberg (1977) found impaired breeding of four species of passerines, also in Sweden. The species included Pied Flycatcher (*Ficedula hypoleuca* Pallas), Bluethroat (*Luscinia svecica* L.), Reed Bunting (*Emberiza schoeniclus* L.), and Willow Warbler (*Phylloscopus trochilus* L.). Breeding impairment was manifested as impaired eggshell structure and decreased nesting weight. Nyholm and Myhrberg (1977) and

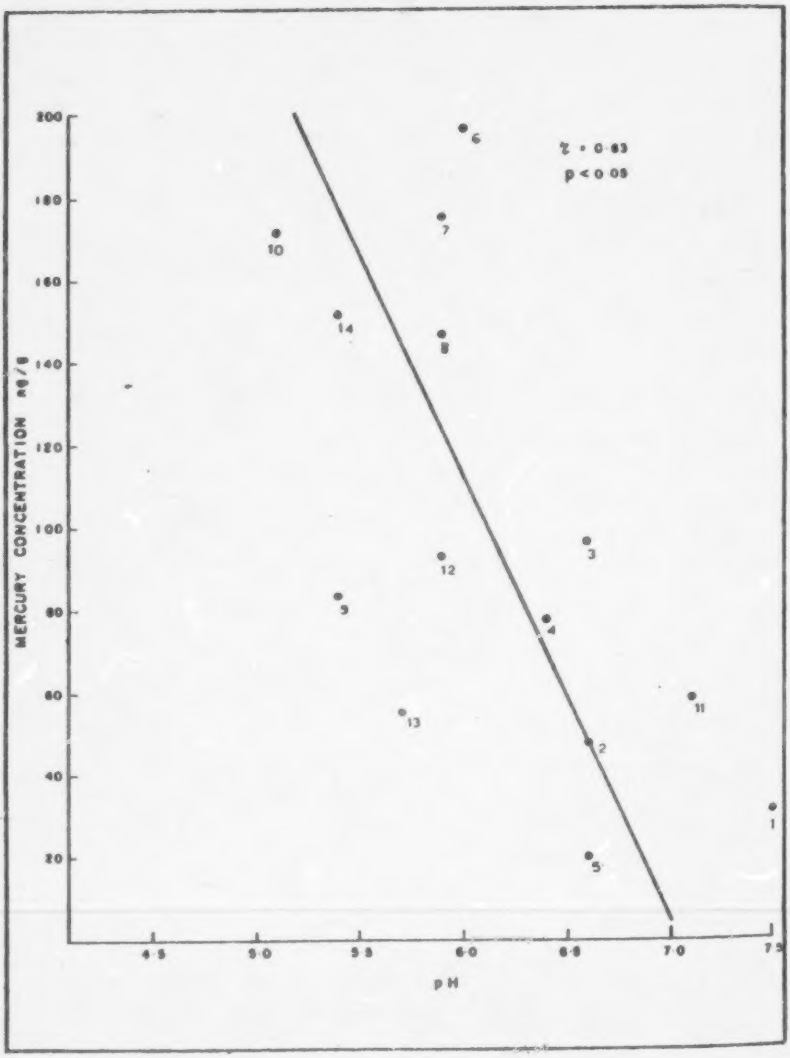


Figure 47. Mercury concentrations in yearling yellow perch and epilimnetic pH relationships (Suns et al. 1980) for the followin lakes (1978 data):

LAKE #, NAME	TWP.	LAKE #, NAME	TWP.
1. Duck Lake	Minden	8. Dickie Lake	McLean
2. Little Clear Lake	Sinclair	9. Leonard Lake	Monck
3. Harp Lake	Sinclair	10. Heney Lake	McLean
4. Bigwind Lake	Oakley	11. Cranberry Lake	Guilfor
5. Nelson Lake	Powell	12. Healey Lake	McCaule
6. Chub Lake	Ridout	13. Clear Lake	Stanhop
7. Crosson Lake	Oakley	14. Fawn Lake	McCaule

Eriksson et al. (1980) suggested that impairment was caused by uptake of Al or other trace metals from metal-contaminated aquatic insects living in acidified habitats.

Table 19 is a summary of potential effects on selected species of birds and mammals dependent upon the aquatic ecosystem for their food and habitat. This summary is based solely on feeding habits, as research on the impacts of acidification on vegetation structure and productivity relating to wildlife habitat is at a preliminary stage.

Effects on Unique Ecosystems Including Rare and Endangered Species

Documentation of acidic deposition effects on unique ecosystems and rare and endangered species is sparse at the present time. Negative effects on rare species will result in a decreased genetic diversity. Aesthetic values of affected ecosystems may be affected by changes in species composition. Many of these sites are presently national parks or national forests in both the United States and Canada and protected by federal laws. Placing an economic value on such ecosystems (and species) is difficult, but their value to society is immense.

The Boundary Waters Canoe Area Wilderness (BWCAW) of northern Minnesota has been recognized as a unique resource for many decades, as evidenced by the various laws passed since 1930 to protect its wilderness state. The attraction of the area (it attracts more recreationists than any other wilderness area in the nation) does not appear to be based on any single factor, but on a combination of related ones, such as fishing and camping in an atmosphere of wild, unpolluted landscape. However, the evergreen forests, clear water and air, rock outcrops, and shallow soils which are the conspicuous ingredients of the BWCAW landscape, are all unusually sensitive to regionally transported pollutants. Small additions of acidity to the thin, rocky soils common in the BWCAW, coupled with geochemical weathering, can be expected to have relatively rapid and irreversible effects on outputs from the nutrient cycles of these ecosystems (Glass and Loucks 1980). These changes would affect groundwater quality and produce soil-mediated changes in cycling rates within the ecosystem.

The BWCAW is in a region comparable in vulnerability to other regions in Europe and North America which have already been severely affected by acidic deposition. Most surface waters have a poor buffering capacity, and many have a low pH (below 6.5) as well. The varied and valuable fisheries resource includes many species that have been reduced, or eliminated, by acidic deposition elsewhere in the United States and Canada. Atmospheric acid sulfate loadings near the BWCAW are at levels associated with the onset of lake acidification in Scandinavian countries. Because of this, it is likely that the most vulnerable lakes are already being affected by acidity from atmospheric sources (Glass and Loucks 1980).

The Kejimkujik National Park in Nova Scotia lies in an area considered to be highly sensitive to acidic inputs because it is composed of shallow, impoverished soils on primarily granitic and quartzite bedrock. Boulder-strewn bedrock plains and poorly drained soils are common. The effects on the salmon of this area have already been reported.

TABLE 19

AVIAN AND MAMMALIAN SPECIES MOST LIKELY TO BE INFLUENCED BY A REDUCTION IN FOOD RESOURCES DUE TO ACIDIC DEPOSITION, FEEDING HABITAT DURING THE BREEDING SEASON, AND ALTERNATE FOOD RESOURCES

Susceptible Food Resources	Feeding Habitat During the Breeding Season	Species	Alternate Food Resources
Fish, aquatic invertebrates, amphibians	Lakes, Rivers	Common Loon (Gavia imuner)	aquatic plants
		Osprey (Pandion haliaetus)	none
	Littoral zone	Great Blue Heron (Ardea herodius)	small mammals
		Belted Kingfisher (Megaceryle alcyon)	some terrestrial invertebrates
		Hooded Merganser (Lophodytes culcullatus)	some aquatic plants
		Ring-necked Duck (Aythya collaris)	some aquatic plants
		Common Merganser (Mergus merganser)	none
		American Mink (Mustela vison)	small mammals, birds
		River Otter (Lontra canadersis)	small mammals
Aquatic invertebrates	Littoral zone	Common Goldeneye (Bucephala changula)	fish
		Red-Breasted Merganser (Mergus serrator)	fish
		Black Duck (Anas rubripes)	aquatic plants
		Green-winged Teal (Anas carolinensis)	aquatic plants
		Mallard (Anas platyrhynchos)	aquatic plants
		Northern Pintail (Anas acuta)	aquatic plants
		American Wigeon (Anas americana)	aquatic plants
	Riparian zone	Spotted Sandpiper (Actitis macularia)	none
Aquatic plants	Wetlands	Muskrat (Ondratra zibethicus)	aquatic invertebrates
		Common Shrew (Microsorex hoyi)	
Aquatic invertebrates	Wetlands and Riparian zone	Common Yellowthroat (Geothylpis trichas)	some terrestrial invertebrates
		Bank Swallow (Riparia riparia)	
		Myrtle Warbler (Dendroica coronata)	
		Eastern Kingbird (Tyrannus tyrannus)	
		Blackpoll Warbler (Pendroica straita)	

A third unique wilderness area considered sensitive to acidic inputs is the high-elevation system of the Adirondack Mountains. These areas consist of shallow, poorly buffered soils and contain, on the mountain tops, many arctic species rarely found in the eastern United States. Acidic deposition is known to affect the fish species of lakes in these areas (Schofield 1976), but effects on terrestrial organisms are not documented. It is of particular importance to determine the tolerance of these unique species to elevated aluminum concentrations.

Effects of acidic deposition on fish populations of the Great Smoky Mountains National Park (GSMNP) have been postulated by Herrmann and Baron (1980). Elevated aluminum concentrations (>1.0 mg/ℓ) in GSMNP streams have been shown to have adverse effects on brook trout populations and sensitive macroinvertebrate populations. The high aluminum concentrations occur in association with acid runoff as low as pH 4.3. No studies have yet discussed the impacts of elevated aluminum concentrations on rare and endangered plant species (and other more common species) found in the southern Appalachian area, including the GSMNP.

CONSIDERATION OF EVIDENCE FOR IRREVERSIBLE IMPACTS

Researchers differ and the evidence seems to be conflicting as to whether the geochemical alteration of watersheds due to acidic inputs should be viewed as irreversible, and, if so, on what scale. Irreversibility can be viewed as a failure to recover over geological time; but, for natural resource systems, an incomplete recovery to a prestressed or undamaged state over a few decades, for all practical purposes, may be regarded as irreversible. The following sections summarize the concepts involved and the evidence on both sides of the question.

Depletion of Buffering Capacity

The possibility of irreversible reduction in buffering capacity of lakes and watersheds is one of the most serious potential impacts of acidic deposition. Once the proton-accepting materials, which hold pH in a biologically acceptable range, are lost from the soil water and stream base-flow, free H or its surrogate, free Al, rise quickly to toxic levels, seriously weakening the biota. The pH of an aquatic system is a product of a dynamic equilibrium between the system and its watershed. Large additions of acidic substances, including a mobile anion such as sulfate, have the potential to modify this equilibrium in geologically sensitive watersheds by consuming and depleting existing (reserve) alkalinity. The earlier data indicating negligible retention of sulfate and reduced alkalinities over several decades suggest this has occurred in a few areas.

The ability of lake water to resist pH depression when acid is added (i.e., buffering capacity) depends on its alkalinity and annual alkalinity formation. The alkalinity of the water depends on the presence of anions, or other species, which can take up protons. In most natural waters, alkalinity is largely a function of bicarbonate, but other substances, such as organic acids are important in the low alkalinity lakes most susceptible to acidification. When lake water is titrated with acid, the change in pH per unit of added acid (i.e., the slope) varies as successive buffers are protonated, each acceptor taking up protons in its own characteristic way. Lakes of moderate pH show successive buffering in the titration curves shown in Figure 48. In a whole lake system, this process is further complicated by the variable mixing processes in the lake, and the spatial and temporal changes in biological productivity, which also contribute proton uptake capacity (Zimmerman and Harvey 1979).

When titration is considered for an entire watershed, as may be the case during sustained long-term atmospheric acidic inputs, additional buffering processes can occur. Contact between protons in water and the solid buffering materials in the soils is not assured, depending on hydrologic flow patterns within both the upper ("inter-flow") and deeper soil horizons. Periods of peak runoff, when much of the "surface" water penetrates only a few centimeters into the soil, are often associated with acid flushing (low pH). This process is more likely to occur when watershed buffering is naturally low or has been depleted by long-term acidic input. In addition, inclusion of the soil system in the buffering reactions introduces new sources of buffering which can retard pH depression in the system, but lead to the mobilization of other cations. When soil pH is less that 5.0, the displacement of aluminum from exchange sites becomes a source of buffering (where it is present); however, in the process, aluminum takes on a soluble, often toxic, form, with risks for both terrestrial and aquatic biota.

The hypothesis that acidification of surface waters by atmospheric acidic inputs can be viewed as a large-scale titration has been articulated by Henriksen (1980) and supported with data from North America and Scandinavia (Wright et al. 1980). Nearly all lakes, except those dominated by acid bog drainage water, are normally bicarbonate buffered, with pH greater than 6.5. By stoichiometry, addition of acid from the atmosphere will consume alkalinity, but the pH will fall only slightly, as long as some bicarbonate remains. Thus, for a lake to remain bicarbonate buffered, acidic input must be less than or equal to the acid-neutralizing capacity of the Ca and Mg input to a lake. Long-term (more than 50 years) records of decreasing alkalinity in a water supply reservoir in the Adirondacks suggest that alkalinity has declined with continued atmospheric acidic input (C. L. Schofield, personal communication). As bicarbonate and any other buffers are depleted, Henriksen suggests that lakes enter a transition phase, characterized by severe pH fluctuations (1-2 units) and associated stresses on fish and other aquatic biota. This transition phase is a time when the lake is particularly susceptible to seasonal pulses of acid (e.g., snowmelt) and to the incomplete "mixing" of water and soil during flushing events. According to this view, a lake may exist in a transition phase until almost all carbonate (or other buffers) in the watershed are consumed.

However, given continued acidic input, this stage is relatively ephemeral. For example, Wiltshire and Machell (1981) found that surface water pH values in Nova Scotia have a bimodal pH distribution, with the fewest lakes at pH 5.5, approximately in the middle of Henriksen's "transition phase". Scandinavian and Adirondack data also support these results (Wright and Gjessing 1976, Schofield 1976, Hutchinson et al. 1978). If watershed titration is occurring, then ultimately lake pH should approach

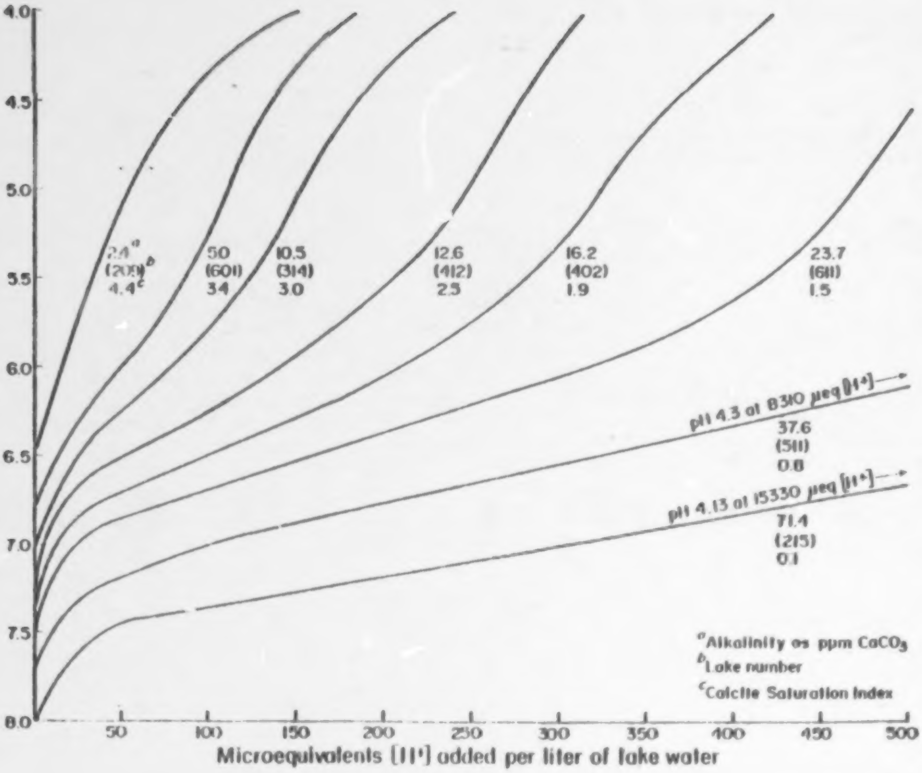


Figure 48. Effect of acid addition on the pH of water from selected Boundary Waters Canoe Area Wilderness-Voyageurs National Park lakes (Glass and Loucks 1980).

5.0, as added H depletes the bicarbonate alkalinity and sulfate deposition provides the anion. As H approaches higher concentrations (lower pH), buffering occurs by aluminum, organic compounds and other proton acceptors. Although one cannot be certain, these appear to be the observed responses, and it is at this stage that fish and other biota become severely depleted or absent.

The hypothesis that a relatively irreversible titration of the base status and buffering capacity of a watershed can take place is a simplification of the complexities of lake/watershed buffering discussed in previous sections. The variety of potential sources of buffering, water flow patterns, and rates of acidic deposition and flushing, all tend to make each lake/watershed system unique. However, the general pattern of observed responses is consistent with the known low buffering capacity of the geology and soils, and with present equilibrium theory for these systems. The effects can be reversed only by regeneration of buffering capacity over a period of unstressed geological weathering during which excess sulfate can be flushed from the soil. If acidic inputs continue to exceed sulfate retention capacity and the rate of alkalinity renewal, then theory suggests that water quality of aquatic systems cannot be restored.

Soil Cation and Nutrient Depletion

A second, apparently irreversible, consequence of watershed titration is the loss of soil cations, particularly Ca and Mg, which can lead to decreases in soil fertility (Overrein et al. 1980). Likens et al. (1977) summarized the watershed level dynamics of a variety of anions and cations over an 11-year period at Hubbard Brook. During this time there were net outputs of Ca, Mg, K, Na and Al at a combined rate that exceeded the rate of H deposition. The difference was attributed to internal sources of H, although equilibrium theory suggests that smaller net losses of these cations would be accounted for by internal sources of H and external sources of anions prior to the acidification of rainfall inputs. In the 1964-1974 period, virtually all of the H deposited from the atmosphere was taken up by the system, in exchange for the above cations. The extent to which these cation losses represent a significant depletion of total available material is unknown.

Similar results are reported by Harvey et al. (1981) who found cation denudation at a variety of watersheds in North America and Scandinavia. In trying to distinguish the various processes accounting for the weathering and cation export, they find that the sum of the H^+ input, bicarbonate output and NH_4^+ input usually balances the sum of the output of metal cations and nitrate input (Table 20). H^+ and NH_4^+ are obvious sources of hydrogen ion for exchange, and HCO_3^- output is a measure of carbonic acid weathering. Nitrate has the effect of neutralizing H^+ by generating an OH^- when it is taken up in the nitrogen cycle. If H^+, NH_4^+ and HCO_3^- in the watershed do not balance metal cations and nitrate, organic compounds are suggested as the weathering agents.

If cation denudation depletes the stock of nutrients of easily weathered soil, fertility decreases can result (Abrahamsen 1980). These responses should be tied to the process of watershed titration, but the connections are unclear at this time. More data are necessary on rates of chemical transformation in the soils, the relative role of acidic deposition, nutrient dynamics, and the nutritional requirements of the plant community.

Table 20. COMPARISON OF ACIDIC INPUT AND CONSUMPTION FOR HARP LAKE SUB-WATERSHEDS ($\Sigma M = Ca + Mg + Na + K$)[†].

Sub-watershed	ΣM	$H^+ + H_2CO_3$	$\Sigma M + NO_3$	$H^+ + H_2CO_3 + NH_4$
3	100.8	96.1	129.5	126.7
3A	110.0	99.8	126.1	131.2
4	81.6	105.3	115.0	134.8
5	100.9	94.0	134.7	124.4

[†] Numbers are averages for 2 yr (1977-78); net mass balances are in meq m^{-2} yr^{-1}.

Loss of Gene Pools (Unique Ecosystem Components)

The most serious irreversible biological effect of acidic deposition is species extinction within sensitive regions. The organisms most threatened include amphibians, fish, crustaceans, molluscs and some aquatic insects (see previous sections). Elimination of fish populations in numerous water bodies has already occurred in Scandinavia, the Adirondacks and parts of Ontario. For these sensitive organisms, even a partial loss of populations bearing genetic characteristics intolerant to H, Al, or heavy metals, could result in a relatively permanent mark on these populations. As geographic movement of these lacustrine life forms is limited, recovery of pre-stressed genetic characteristics probably can be considered only over millenia. The ecological importance of this impact will depend on the possible availability of stocks which might substitute in the impacted areas.

SULFATE LOADING TARGETS CONSISTENT WITH PROTECTION OF AQUATIC ECOSYSTEMS

The previous sections have shown chemical and biological changes in surface water systems, including pH depression and associated effects over long-term, annual, seasonal and event-related time series. Most of the results are consistent with the explanation that they result from acidity associated with the SO_4 ion originating from atmospheric deposition. This section will consider the significance of these levels of chemical alterations, with emphasis on the levels of atmospheric input which could be viewed as having "no effect" or an "acceptable effect" on the most sensitive streams and lakes. Evaluation of a "no effect" loading threshold or "sustainable" loading rate which may yield moderate but "acceptable" effects, requires consideration not only of mean trends in surface water and precipitation pH and sulfate concentrations, but also of the frequency and severity of brief periods during which much of the response to the loading dose is expressed.

The following are the principal findings presented in previous sections which bear on interpreting the significance of present pollutant loadings and the estimation of acceptable or "target" loadings:

1. Precipitation over most of eastern North American is currently acidic, with acid concentrations up to 100 times those expected for rainfall in equilibrium with atmospheric carbon dioxide and other natural constituents.

2. Large quantities of sulfate and nitrate are deposited with the acid in precipitation.

3. Two to five hundred thousand lakes in eastern North America with low alkalinities are being subjected to elevated acid loadings. Such lakes, and their associated streams, usually suffer low pH and elevated metal concentrations for short periods of time, particularly during snowmelt and other periods of heavy runoff.

4. Evidence of stressed fish populations has been observed in lakes which experience short-term low pH and elevated metal concentrations. Adult fish kills have been observed in one study lake experiencing these conditions.

5. There are numerous examples indicating many streams and lakes in Canada and the United States are losing alkalinity and becoming acidic. Fish populations which have survived the short-term low pH conditions seem likely to be lost eventually if the pH continues to decline to values causing reproductive failure.

6. Hundreds of lakes in eastern North America are showing serious acidification and fish populations have been lost. The responses by other biota are quite variable, depending on the taxa.

The Relative Significance of Sulfur and Nitrogen Deposition to Acidification of Surface Waters

Results presented in the previous sections have shown that four major ions of concern in acidic deposition, H, NH_4, NO_3, and SO_4, all have some potential for altering lake and stream water quality. Soil and plant interactions with nitrate ions allow the acidic input from nitric acid to be largely assimilated (usually > 80%) by the terrestrial portion of the watershed (McLean 1981). However, in many northern and poorly buffered acid bedrock areas, biological interactions with the sulfate ion are small in comparison to the mass balance of sulfur (Harvey et al. 1981). Christophersen and Wright (1980) reported that the sulfur export from a watershed in Norway was essentially the same as the total input over the period November 1971 to October 1978. Thus, SO_4 can be viewed as a relatively conservative anion in many watersheds and, therefore, likely to show a direct relationship between concentrations observed in precipitation and those observed in lakes and streams for basins where there are no significant geological sources or sinks of sulfur.

There are additional aspects to the issue of the dominant anion associated with the acidification of surface waters. These are:

1. the relative magnitude of SO_4 and NO_3 in the rain and snow inputs, and their variation during the year;

2. the relative magnitude of the biological interactions of both anions in watersheds, as they are affected by biological activity at different seasons and by biomass accretion or decomposition over longer periods; and

3. the potential for alkalinity production in aquatic systems through the addition of NO_3 when N is a partially limiting nutrient for plant growth.

Data already presented here, (Figures 5 to 14 [maps]) and other data presented by Galloway et al. (1980), McLean (1981) and by Harvey et al. (1981) indicate acid sulfur inputs exceed acid nitrogen inputs over eastern Canada and the U.S. on an annual basis. The net yield of these anions to streams and lakes, however, is predominantly SO_4, on an annual basis (Harvey et al. 1981).

Evidence as to why nitrate deposition is not the main driving force behind surface water acidification is given in Table 21a. Data for five streams with variable pH show that as the acidity increases, the relative importance of nitrate declines. The median value of the H/N ratio is very low for Harp Lake 4, mainly due to the hydrogen ion concentration being so low. In Dickie Lake 5, the hydrogen ion concentration is more than an order of magnitude greater, but the median H/N value has increased by 580 times. In other words, as the hydrogen ion concentrations increase, they surpass the nitrate concentrations and the pH of the streams cannot be explained by the presence of nitric acid. Table 21b gives the ratios of H/S for four of the same streams in the Dorset area of Ontario. As the pH decreases, the hydrogen ion concentrations exceed the nitrate, but are much less than sulfate (data for Dickie 5 and Red Chalk 2, are not available).

At Sagamore Lake, N.Y., nitrate concentration in runoff increased during spring pH depression, while sulfate concentrations did not (Galloway et al. 1980). There may be several reasons for the higher nitrate export observed here. These include the higher total loading (Table 1), differences in the pattern of various forest growth stages, and differences in topography which modify runoff patterns and, therefore, uptake by organisms in leaf litter. Still, sulfate concentration in the three study lakes here greatly exceed nitrate concentrations, even during spring runoff.

Nitrate ions which do reach the surface waters can still be taken up by aquatic plants with resulting production of alkalinity. This has been

TABLE 21a RATIOS OF HYDROGEN ION (H) TO NITRATE ION (N) EXPRESSED IN EQUIVALENTS PER LITER FOR SIX STREAMS WITH VARIABLE pH IN THE DORSET, ONTARIO, STUDY AREA FOR 1976, 1977 AND 1978. DATA ARE BASED ON MONTHLY AVERAGE CONCENTRATIONS BUT COMPLETE MONTHLY RECORDS ARE NOT AVAILABLE FOR ALL STREAMS.

Stream	pH Range	H/N Range	H/N Median Value	No. of Months
Dickie 5	3.7-4.7	4.0 -278	29	28
Red Chalk 2	3.9-4.8	7.4 -133	26	24
Harp 6	4.3-6.4	0.07-17	5	24
Harp 5	4.8-6.6	0.01-50	0.4	36
Paint Lake Inlet	4.9-6.7	0.06-4.1	0.25	29
Harp 4	5.3-6.9	0.01-1.9	0.05	36

TABLE 21b. RATIOS OF HYDROGEN ION (H) TO SULFATE ION (S) EXPRESSED IN EQUIVALENTS PER LITER FOR FOUR STREAMS WITH VARIABLE pH IN THE DORSET, ONTARIO, STUDY AREA FOR 1976, 1977 AND 1978. DATA ARE BASED ON MONTHLY AVERAGE CONCENTRATIONS BUT COMPLETE MONTHLY RECORDS ARE NOT AVAILABLE FOR ALL STREAMS.

Stream	pH Range	H/S Range	H/S Median Value	No. of Months
Harp 6	4.3-6.4	0.003- 0.52	0.025	17
Harp 5	4.8-6.6	0.0005-0.17	0.004	36
Paint Lake Inlet	4.9-6.7	0.001- 0.08	0.015	25
Harp 4	5.3-6.9	0.0001-0.01	0.002	36

Source: Scheider, 1981, personal communication.

shown to occur in one of the study lakes at the Dorset location. Reported increases in lake pH from 5.1 to 6.6 over the summer were associated with decreases in nitrate concentrations by photosynthetic processes, and this was given as the explanation for the pH increases (Harvey *et al*. 1981).

On balance, the evidence available, and the published interpretations of that evidence (Harvey *et al*. 1981, Overrein *et al*. 1980), lead to a conclusion that, for surface water systems, recent increases in acidity are primarily the result of increased sulfuric acid reaching these waters. In addition, the changes in SO_4 observed in surface waters are being shown to be attributable to the sulfate and sulfuric acid loading. Although nitric acid has been observed to contribute some acidity in surface waters during snowmelt, in some locations, there is little theoretical or empirical evidence for anticipating appreciable reduction in lake or stream acidification from a reduction in nitric acid inputs. Conversely, the evidence is strong that *reduction in sulfate loading will reduce the observed sulfate concentrations and associated acidification of surface waters*.

Methodologies for Estimating Target Loadings

The evidence available on the effects of acidic deposition on aquatic resources indicates present loadings are in excess of the neutralizing capacity of sensitive soils and watersheds and that relief from these effects can be expected from a reduction in the more conservative acid ion inputs. This section, therefore, will explore the question of what levels of acid or sulfate loading would be unlikely to produce any further negative effects, i.e., a "target loading". Implicit in this concept is the idea of a single (or a series of) sulfate deposition values (as a surrogate for hydrogen ions) indicating a loading rate that will prevent the damage being observed to the aquatic ecosystem lying within watersheds of specifiable sensitivity.

Surface water quality alterations fall into two categories: short-term, which describes the low pH conditions during snowmelt or heavy rains, and long-term, which describes the relatively permanent reduction in alkalinity, and the corresponding low pH values in surface waters all year long. In North America, the short-term effects are probably the most common in terms of numbers of lakes and rivers affected. While the chemistry of these effects are fairly well defined, and the biological consequences are known to be severe in some cases, the overall processes are not yet fully understood. Thus, an empirical approach to the watershed "dose/response" relationship is the only one available at this time.

The second effect, long-term acidification, has altered large numbers of lakes in North America, but the percentage of the lakes and rivers profoundly acidified remains small. The rate of loss of alkalinity and associated increase in acidity is not yet defined beyond the fact that it seems to occur over a period measured in decades. The biological condition of the acidified lakes and streams has been relatively well defined. Consequently, this report makes use of the long-term acidification "models" developed from the most extensive data bases available, largely from Scandinavia, supplemented by North American data, in order to derive preliminary estimates of sulfate loading targets.

The acidity and chemical composition of aquatic environments are largely controlled by two factors: the buffering capacity of the geologic components of the basin, and the effective acidity of the precipitation, and the interaction between the two. Biological processes, e.g., production and decomposition, also have an effect. Detailed models of the geochemical processes and aquatic ecosystem impacts are not fully validated at this time. Their development and application will require detailed information on basin geology, hydrology and biotic interactions, unlikely to be available soon for widespread application. Therefore, it is possible, at present, to determine the permissible carrying capacity of basins for acidic loadings in only a general way, using the presently observed behavior of streams and lakes to derive relationships between measures of acid loading and system response. Such models are still under active development, but have advanced to the point where a preliminary application is possible, although it is important to stress that full validation remains to be achieved. Several of these models are discussed below, in order to evaluate relationships between present acid loadings and lake or stream sensitivity, as they are reflected in each approach.

1. Almer-Dickson Relationship

One way to summarize the relationship between lake pH and atmospheric loading of acidic pollutants is to plot observed lake pH versus total sulfate loading, as summarized by Almer and Dickson (Almer et al. 1978) (Figure 49). Various combinations of watershed characteristics are reflected in the family of curves connecting the different sets of lake data. A larger number of curves may be envisioned, each representing lake/watershed systems of comparable sensitivities as they apparently respond to increases in atmospheric acidic inputs. The curves are superficially similar to titration curves, as might be expected, and each shows buffering at high pH, then a rapid drop (as this buffering is depleted or sulfate absorption capacity is exceeded) to lakes with low pH and minimal buffering. The pH in the more sensitive lakes drops sooner and more rapidly, relative to the loading of SO_4 which, in this model, is considered to be the surrogate of the acid.

A graph of sulfate deposition versus lake pH, such as Figure 49, could be used to estimate lake/watershed sensitivity, and thereby, acid loading tolerance if the sensitivity response curves were defined in terms of water chemistry parameters for each watershed of interest. Unfortunately, the response curves for each family of sensitivites are not defined individually, although one may infer that they are related to the buffering capacity of the basin. The latter can be quantified through use of the calcium concentration of the waters (Henriksen 1980) or the cation denudation rate (Thompson 1981). In any case, Figure 49 represents the range of sensitivities found in Scandinavia, with results from several North American studies added. (Since some of these data are available only as total wet or bulk deposition, allowances should be made in the horizontal scale.)

Examination of Figure 49 suggests that total annual sulfate loadings of less than 15 to 17 kg/ha would be unlikely to degrade lakes of the type represented in curve (1). However, if the lower range of the data distribution is viewed as a "family" of the most sensitive lakes and streams, they appear to be barely free of potential acidic loading effects

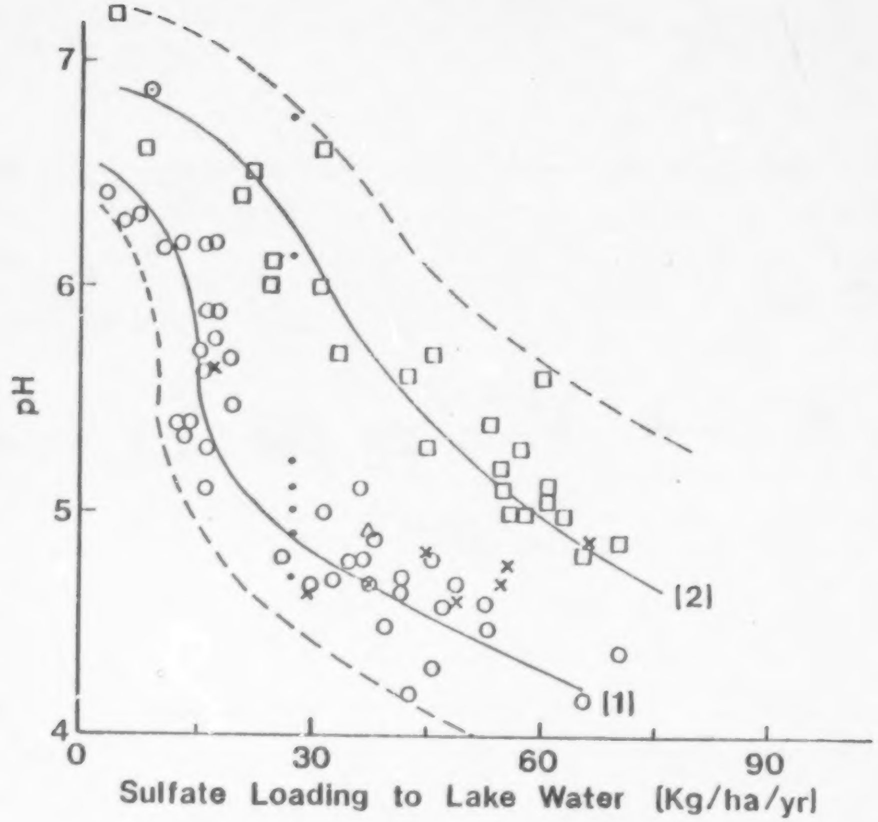


Figure 49. Effects of various sulfate loading rates (wet plus dry) on lake pH for lakes in very sensitive (1) and somewhat less sensitive (2) surroundings in Sweden (modified from Almer *et al*. 1978). Added points are for: (·) Florida (Crisman and Brezonik 1980); (θ) Como Creek (Lewis and Grant 1980); (Δ) Hubbard Brook (Likens *et al*. 1977); and (x) Norway (Wright and Snekvik 1978).

at an annual rate of 9 to 12 kg ha^{-1} yr^{-1} (wet plus dry deposition). Thus, two "tolerances" can be defined, the latter associated with protection of nearly all sensitive aquatic resources, and the former designed to protect somewhat less than all sensitive lakes, i.e., only the portion of the "sensitive" resources that lie above curve (1) in Figure 49.

Since these curves were developed primarly on the basis of Swedish data, and are not actual observations of acidification responses over time, these estimates of acid loading tolerances must be viewed cautiously for application in a North American context.

2. Henriksen Nomograph

Henriksen (1980) presents a model based on Norwegian data and the concepts implicit in titration of a bicarbonate-buffered watershed/lake system with strong acid (principally H_2SO_4) from the atmosphere. In the process, bicarbonate is replaced by sulfate and lake pH can fall below 5, with consequent effects on aluminum mobilization and lake biota. These relations are basically the same as those in the Dickson work, and are further developed by Thompson (1981). The model is summarized in the nomograph (Figure 50), using two key measurements:

1. ambient concentrations of in-lake calcium (or Ca + Mg), as an estimator of the pre-acidification alkalinity; and
2. lake sulfate concentrations (in excess of marine salt input), as an estimator of H added to the system.

The resulting semi-predictive nomograph is divided into three sections:

1. bicarbonate lakes, where original alkalinity was high and/or added H is low, so that the lakes remain bicarbonate buffered;
2. acid lakes, where original alkalinity was low relative to acidic inputs, and all bicarbonate appears to have been depleted by the acid addition; and
3. transition lakes, in which bicarbonate appears to be undergoing reduction (or is almost depleted) and large pH fluctuations may occur during acid pulse events.

The transition phase, in which the lake apparently shifts from a bicarbonate-buffered equilibrium, at moderate pH, to an acidified system represents the critical phase which requires prediction. Thompson (1981 and later in this report) has shown that this process is adequately represented by sulfate replacement of bicarbonate as the major anion in runoff. If cation weathering (approximated by Ca plus Mg in Henriksen's model) does not change in response to sulfate loading, the cation concentration of waters (the horizontal dashed line for Ca plus Mg as a surrogate for total cations) may be used to estimate a sulfate loading which would retain a mean annual aquatic pH in the desired range. While the constancy of the cation weathering is yet to be verified due to lack of long-term records (i.e., alternatively, the sloping dashed line, Figure 50), Henriksen has shown that small changes would not have significant effect on most applications in Norway.

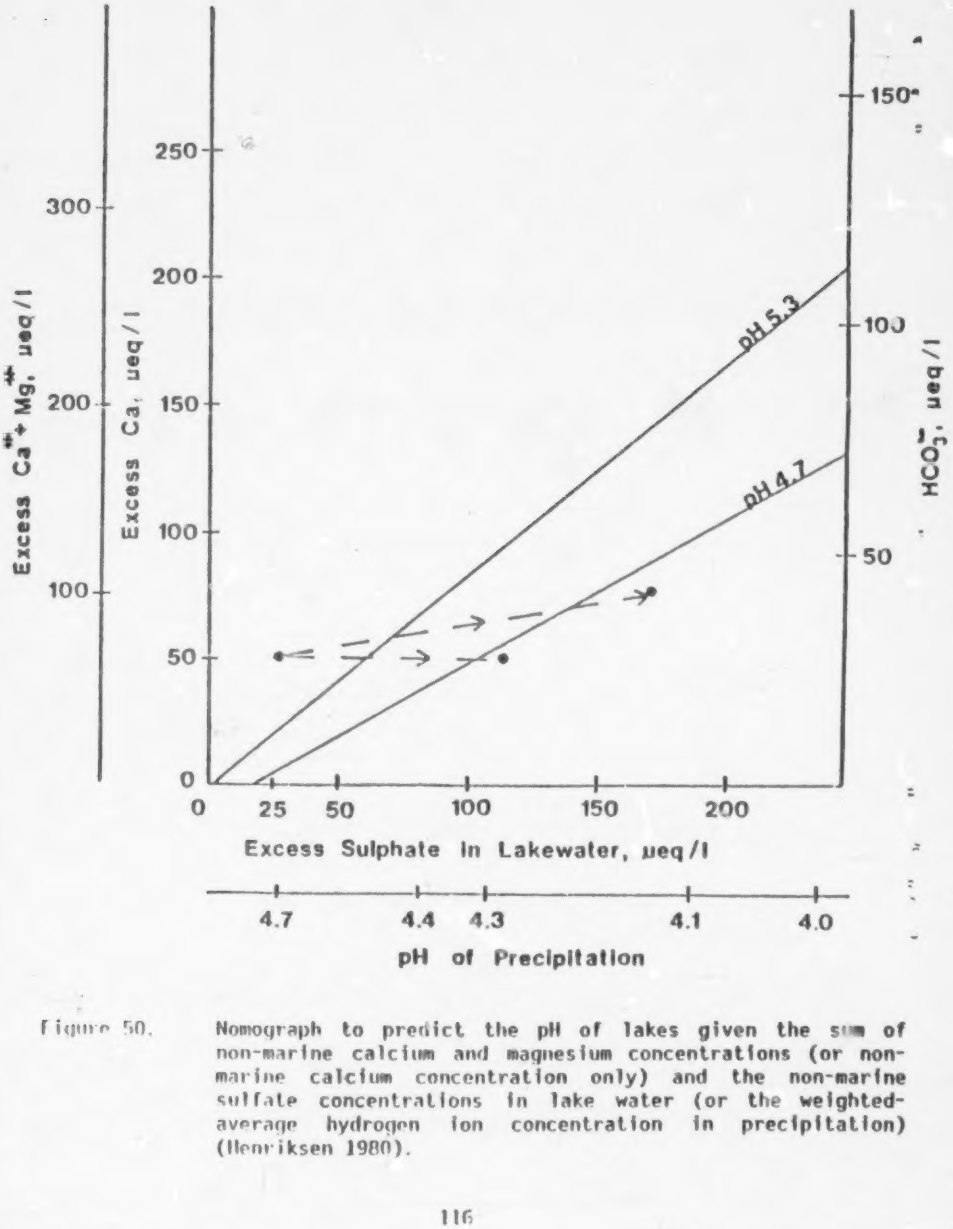


Figure 50. Nomograph to predict the pH of lakes given the sum of non-marine calcium and magnesium concentrations (or non-marine calcium concentration only) and the non-marine sulfate concentrations in lake water (or the weighted-average hydrogen ion concentration in precipitation) (Henriksen 1980).

Henriksen (1980) also derived an empirical relationship between the sulfate concentrations of surface waters and input precipitation as:

$$SO_4(W) = -19 + 1.9\ SO_4(P)$$

where concentrations are in µeq/ℓ, (W) refers to surface waters and (P) to precipitation. This relationship reflects the concentration of SO_4 due to evapotranspiration and also includes the contribution of dry deposition of sulfate. The values may differ in North America, or from location to location, but are used here for purposes of estimation.

Figure 51 shows the distribution of lakes in Norway in terms of calcium and pH. There are numerous lakes having calcium concentrations less than 50 µeq/ℓ. However, if this value is chosen as a limit above which lakes are to be maintained at pH greater than 5.3, then a target sulfate precipitation concentration can be derived which should protect those lakes. A distribution of North American waters in relation to calcium (or to total cation concentrations) is not available but a lower limit of 50 µeq/ℓ would include all except the more sensitive waters, thereby possibly defining an "acceptable" SO_4 loading target.

From Henriksen's nomogram, [illegible] can calculate that a sulfate concentration in surface waters of about 50 µeq/ℓ would permit pH to remain above 5.3 for waters having calcium concentrations greater than 50 µeq/ℓ. Using the above relationship, this concentration in surface waters would result from a precipitation concentration of about 40 µeq/ℓ of sulfate (14 kg ha^{-1} yr^{-1} of wet deposition, assuming 70 cm of precipitation). If annual rainfall is 100 cm this concentration would result in a deposition of about 20 kg ha^{-1} yr^{-1} of sulfate.

Apparently, even lower SO_4 concentrations in precipitation would be required to protect lakes with calcium levels below 50 µeq/ℓ. For lakes with only 25 µeq/ℓ of calcium, protection from likely acidification (the entry level to the transition phase) would require precipitation with no more than 23 µeq/ℓ of sulfate (8 kg ha^{-1} yr^{-1} for 70 cm precipitation and 11 kg ha^{-1} yr^{-1} for 100 cm).

3. Cation Denudation Rate (CDR) Model

The CDR model (Thompson 1981) relates the rate of acid (excess SO_4) loading to the rate of major cation denudation of large watersheds, thereby predicting the mean pH of rivers. If the rate of excess SO_4 loading is less than the CDR by 20 meq m^{-2} yr^{-1} (i.e., the HCO_3 residual equals 20 meq m^{-2} yr^{-1}), the model predicts the resulting runoff water (at a yield of 1 m/yr) will have a mean pH of 5.6. As the rate of excess SO_4 loading approaches the CDR, the runoff water will approach a pH of 5.1 and will carry little or no alkalinity. Figure 52 shows 1973 data for rivers in Nova Scotia and Newfoundland that have mean runoff rates near 1 m/yr. These rivers have a total CDR ranging from 55 to 200 meq m^{-2} yr^{-1}. In 1973 at least three of these rivers received excess SO_4 loads exceeding their CDR, and consequently had no alkalinity. The resulting pH was less than 5.1.

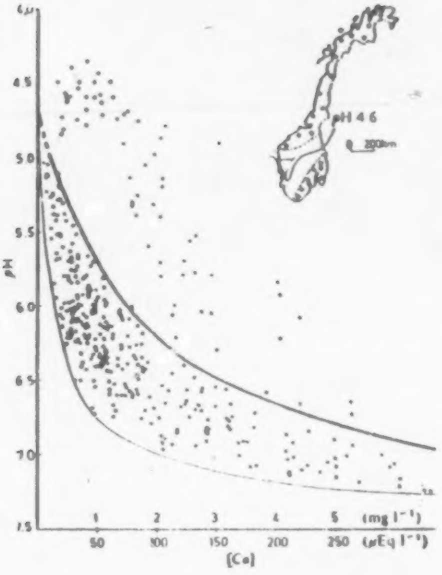


Figure 51. pH and calcium concentration in lakes in northern and northwestern Norway sampled as part of the regional survey of 1975, in lakes in northwestern Norway sampled in 1977 (o), and in lakes in southernmost and southeastern Norway sampled in 1974 (·). Southern Norway receives highly acidic precipitation (pH 4.2-4.5) and a large number of lakes have lost their fish populations due to high acidity. Inset shows areas in which these lakes are located. Areas south of isoline receive precipitation more acidic than pH 4.6 (Henriksen 1979).

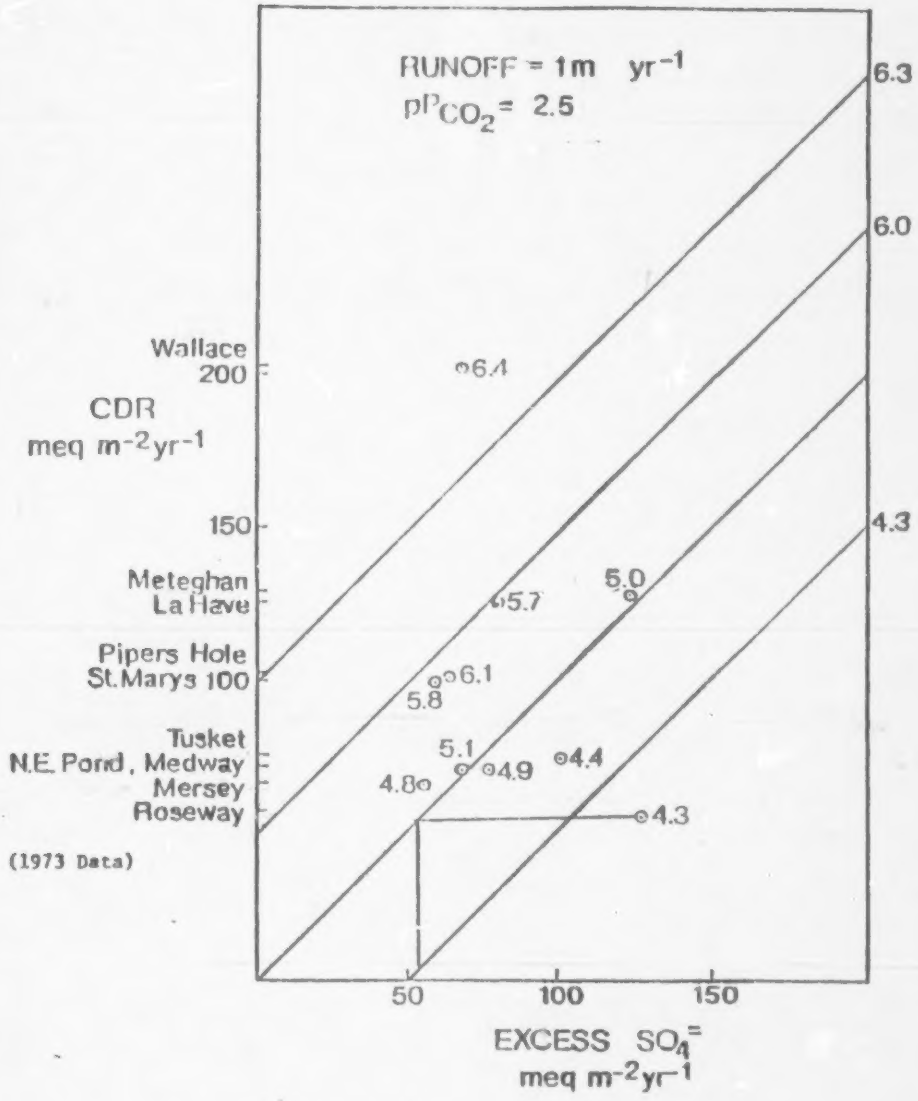


Figure 52. Cation denudation rate model applied to rivers of Nova Scotia and Newfoundland. (Thompson 1981).

Questions have been raised as to whether atmospheric loads of strong acid alter the rates of chemical weathering in watersheds, and therefore the CDR. Comparisons of data for very soft water rivers in southern Nova Scotia between 1954-55 and 1973 (Thompson et al. 1980) show lower pH (and higher excess SO_4) in the more recent data, but no significant change in major cation loads.

Analysis of long term monitoring data for rivers in Newfoundland shows that cation loads generally correlate well with discharge, but are somewhat higher when groundwater is the major source of flow. They are somewhat lower when snowmelt or heavy rainfall is the major source of flow (Thompson 1981). Such considerations indicate that a river would tend to have lower pH at time of higher flow. There is no evidence, to date, of any long-term trends toward higher or lower CDRs for these rivers (based on ten or more years of monthly sampling data), but this appears to be a short period in comparison to the period of elevated atmospheric sulfate deposition.

By use of this model, it may be estimated that the Roseway River, (Figure 52) having a CDR of 56 meq m^{-2} yr^{-1}, would be returned to a pH of about 5.3 if the excess sulfate load were reduced to about 40 meq m^{-2} yr^{-1} (20 kg ha^{-1} yr^{-1}) based on the 1973 data. It, apparently, could be returned to a pH of 5.8 or 6.0 if the sulfate loading were reduced to the range of 10 to 20 meq m^{-2} yr^{-1} (5 to 10 kg ha^{-1} yr^{-1}).

While no historical precipitation data are available, it is suspected that the loadings in 1973 were well in excess of 20 kg ha^{-1} yr^{-1}. Current loadings are just in excess of 20 kg ha^{-1} yr^{-1} (Figure 7) and the pH of the Nova Scotia and Newfoundland rivers has increased somewhat in recent years (Figure 25). It should be noted, too, that the CDR model is similar to the model of Henriksen (1980) when sulfate is plotted in lake concentration form, except that it requires sums of cations rather than Ca + Mg.

4. Short-Term or Episodic Effects

The question has often been raised, "How long does it take before the lakes become acidic?" The previous sections have indicated relationships for lakes and streams that have already been acidified. However, the rate of change is one of the least well-defined aspects of the acidification phenomenon.

The rate-of-change questions become less relevant in light of evidence that current acid loadings are causing damage to fisheries and other biota due to short-term exposures to low pH and associated high metal concentrations (as reviewed earlier in this report). The pH of lakes or streams tends to fluctuate considerably during the year, and average annual pH is a composite of these patterns. Thus, summertime or annual pH has questionable value for determining impacts on organisms which respond to H or metals over a few days. This, plus the known significance of brief acute exposure (review by Spry et al. 1981), suggest that the magnitude and duration of short-term increases in H, associated with a defined "flushing event", could be used as a model for evaluating critical dose/response relationships in stream ecosystems, as opposed to lakes (Loucks et al. 1981).

Research on brook trout and white sucker by Baker (1981), Baker and Schofield (1980), on Atlantic salmon by Daye (1980a,b) and Daye and Garside (1975, 1977, 1980a, 1980b), and related research by Beamish and Harvey (1972), Beamish (1974a, 1974b, 1976), and Harvey (1975, 1979, 1980) have provided a broad understanding of the response of several pH-sensitive fish species to both long-term and short-term elevated H and aluminum exposures. Mortalities have been documented for chronic pH depression, and effects on egg viability, hatching success and adult survival for short-interval acute H and aluminum exposures are reasonably well known (Baker and Schofield 1980). The experimental data base developed by Baker (1981) has been cast in generalized form for the purpose of developing a similation model of the effects of episodic H and Al flushing (U.S. FWS 1981).

Among the experimentally-based relationships developed by Daye, Garside, Baker and Schofield is a recurring pattern summarized as a descriptive model by Loucks *et al*. (1981):

1. the short-term acute exposure or "shock" effects, including responses to aluminum, can take place in two to four days of exposure with as little change as 0.5 to 1.5 units of the pH scale; and

2. these shock exposures can be expected to occur in waters with a broad range of pH above the level at which chronic effects occur.

Stream water chemistry studies from a number of locations (see Table 22) show pH depression during flushing events, e.g., from 0.3 to 1.0 pH units during snowmelt in northern Minnesota (Glass 1980), 1.0 unit on the Shaver's Fork River in West Virginia (Dunshie 1979) and from 1.0 to 2.0 units in one less-acidified watershed being studied in the Adirondacks (Galloway *et al*. 1980). Values in this range have also been reported for Hubbard Brook (Likens *et al*. 1977). A third lake studied by Galloway at the Adirondack site is chronically acidified at a pH of about 4.8 and shows no pH depression during flushing events. Thus, pH shock events can be thought of as a phenomenon of watersheds in the "transition phase" of Henriksen (1980). Peak concentrations of aluminum are often associated with these H flushing events (Driscoll 1980).

The maximum pH depression during a flushing event, outside the snow accumulation regions (i.e., southern United States sites), appears to occur during a major rainfall event (in the order of 4 cm rainfall or more) following a rain-free period (Dunshie 1979). Thus a "flushing event" can be defined as an acidic input caused by the equivalent of a 2 to 4 cm rainfall or snowmelt into streams of 0.2 to 5 m^3/S flow, following a period of accumulation of acidic deposition in snow of surface litter and foliage. Part of this deposition could occur during light rains or from fog.

Table 22 summarizes a wide range of available data relating sulfate loading to observed pH depression and biological effects. Sulfate loadings of as little as $\cong 10$ kg ha^{-1} yr^{-1}, as presently observed at the E.L.A. in northwestern Ontario, is required before detrimental pH depression is

TABLE 22

PERIODIC pH DEPRESSIONS OBSERVED IN STREAMS AND LAKES WITH DIFFERENT SULFATE LOADINGS

Location	Annual Sulfate Loadings kg SO_4 ha^{-1} yr^{-1} by wet Deposition	Lowest pH Observed	Δ pH Largest Difference Between Spring pH and Summer or Winter Values	Observed Biological Effect
Panther L. ILWAS Project New York	38	4.8	2.5	No biological lake data available, downstream hatchery fish mortality observed.
Tovdal R. Norway	≅ 40	pH shock suspected but no field measurements taken during the fish kill		Fish kill (sea trout).
Haliburton Ontario (4 streams)	≅ 30	4.1	1.1	No studies.
(lake outflows)	≅ 30	4.8	1.3	A year class missing in white sucker populations in one of the lakes. Limited field studies completed.
L. Timmewatten Sweden (1970)	≅ 40	4.2	0.8	Wild population of minnows has disappeared.
Sweden (1972)	≅ 40	4.3	1.1	Caged sea trout and minnows experienced 68% and 59% mortality.
Shavers Fork W. Virginia (stream)	> 30	5.6	0.9	Conditions caused by heavy rain. No biological studies.
Northern Minnesota streams	≅ 14	5.8	0.3-1.0	No biological studies.
Plastic Lake Ontario: Inlet	≅ 30	4.0	?	100% mortality of caged rainbow trout.
Plastic Lake Ontario: Outlet	≅ 30	5.0	0.7	13% mortality of caged rainbow trout.
Experimental Lakes Area, Ontario	≅ 10		0.2-0.3	No apparent biological effect.

avoided. Much further research is needed to define the synergistic responses of biota to the pH shock and associated increases in metal elevation concentrations, and also to provide an understanding of the hydrological circumstances which control the acidic pulse occurrence.

Summary of Loadings and Target Loadings

The models and their indicated target loadings have been expressed in terms of sulfate loadings from wet or bulk deposition. The pH of precipitation is commonly measured and is an important parameter related directly to short-term acid shocks. D. W. Schindler (personal communication) has suggested that precipitation pH probably should be no lower than 4.7, and that it may need to be higher to protect the most sensitive resources. He states:

> "Three studies, one in Scandinavia, one in Scotland, and one in Canada have shown that detectable decreases in pH (of lakes) are measurable where precipitation with a pH of 4.7 or less and low alkalinity lakes occur together (Watt et al. 1979; Henriksen 1980). We know from other works that where precipitation is more acidic than 4.7, aquatic damage occurs rapidly (Dillon et al. 1979, Henriksen 1980). Studies at the Experimental Lakes Area, Ontario, have shown that damage at precipitation pH values of 5.0 is not detectable so far. Preliminary evidence suggests that in sensitive areas, a precipitation pH of no less than 4.7 is desirable."

A target loading of 10 kg ha^{-1} yr^{-1} corresponds to about 20 μeq/ℓ in precipitation for 1 meter of rain. If the sulfate were associated with an equivalent of acid, the pH would be about 4.7. The presence of bases or other anions would alter this pH value. Most of the sensitive areas of eastern North America receive precipitation in which the acid content ranges from ½-1 times the sulfate content on a chemical equivalent basis (Barrie 1981). Therefore, the pH values would tend to be higher than indicated in the example given.

On the other hand, the most sensitive areas in central Canada and the U.S. receive annual precipitation ranging from 0.5 to 1 meter. Thus, a 10 kg ha^{-1} yr^{-1} target loading will yield a sulfate concentration of from 20 to 40 μeq/ℓ, with the 40 μeq/ℓ value corresponding to a pH of 4.4 if the acid is present as an equivalent. The pH would range between 4.4 and 4.7 depending on area, but would generally by higher because of the observed relationships between acid and sulfate concentrations in precipitation.

For example, measurements of bulk deposition of sulfate (wet-plus-dry fall) made at the Experimental Lakes Area (ELA) of Ontario show an average recent sulfate deposition of 10.9 kg ha^{-1} yr^{-1} and an average rainfall pH during 1974-77 of 4.86 (Glass and Loucks 1980). The presettlement pH for rainfall in this area appears to have been 5.7 (cf. carbonic acid equilibrium and data for 1955-56 shown by Galloway and Cowling 1978). The bulk deposition data from the ELA show that 70% of the nitrate and sulfate is in a neutralized form. Thirty percent is in the acid form, and the H ions were assumed to divide between SO_4 and NO_3 on a 2:1 ratio. This information yields an estimate of 7.6 kg ha^{-1} yr^{-1} of neutralized sulfate and 3.1 kg ha^{-1} yr^{-1} of acid sulfate producing the net depression in pH. These results, therefore, also show that, depending on the historic potential of atmospheric constituents to neutralize atmospheric acid, presettlement loadings of sulfate (as bulk deposition) in this region must lie between 0 and 7.6 kg ha^{-1} yr^{-1}. For the purposes of the BWCA analysis, Glass and Loucks (1980) used a value of 4 kg ha^{-1} yr^{-1} for background neutralized sulfate deposition.

Table 23 lists the observed sulfate loadings at several study locations and the nature of the water quality effects. Estimates of acceptable SO_4 loadings from different models are shown. A target total loading of 10 kg ha^{-1} yr^{-1} appears likely to cause minimal, if any, damage to highly sensitive aquatic ecosystems. Values of 20 kg ha^{-1} yr^{-1} or more are clearly associated with degradation of the more sensitive surface waters. For the reasons developed previously, it appears reasonable to expect the extent of biological damage to decline as SO_4 loadings to presently affected areas to move toward 10 kg ha^{-1} yr^{-1}. The agreement between the models and the observations is not surprising since the models themselves are based on empirical observations from other lake sets which span the range from lake acidification to negligible effects.

Regardless of the model used to determine threshold loading values, there are variables that lie outside the purview of effects modeling. One of the most important is the number of lakes (placed at risk by a given "loading capacity" or "tolerance") that society may choose not to protect. Lake sensitivity is a function of geochemical processes in highly variable lakes and watersheds; abatement to a level that protects the single most sensitive stream or lake in the U.S. or Canada may not be feasible. Once aquatic systems are inventoried according to defined sensitivity measures, a cutoff point can be determined for various loading tolerances, as can the corresponding number of streams and lakes that may be sacrificed. Present inventories are not sufficiently extensive to permit an unbiased estimate of tolerance profile.

To illustrate the implications of this process, and the role of predictive response models in providing options, Table 24 summarizes the evidence available and the projected consequences of SO_4 loadings at three different intensities, using three different models of the response. The loading levels are:

1. 5 kg ha^{-1} yr^{-1} - a level only slightly above the apparent historic levels of SO_4 deposition in northern-interior-continental land masses;

2. 15 kg ha^{-1} yr^{-1} - a level reflecting somewhat elevated SO_4 deposition, and covering very large areas of the eastern and interior U.S. and Canada; and

3. 45 kg ha^{-1} yr^{-1} - a level representative of the heavily acid-impacted regions of the eastern U.S. and Canada.

The results shown in Table 24 are literal interpolations of prospective responses, using three models discussed previously. The limita-

Table 23. OBSERVED SULFATE LOADINGS AND LOADING VALUES, PREDICTED BY VARIOUS METHODS, TO PROTECT AQUATIC ECOSYSTEMS.

Source	Loadings as total deposition	Loadings as wet/(bulk) deposition	Comments
	(kg SO$_4$ ha^{-1} yr^{-1})		
OBSERVED LOADINGS			
Observed at Hubbard Brook, New Hampshire	55[1,2]	(35)[1]	Acidified lakes in the area.
Observed at Panther Lake, Adirondacks, New York	62[2]	38[2]	Acidified lakes in the area.
Observed at Dorset, Ontario	42[3]	30[3]	pH depression causing fish kills.
Observed at Kejimkujik, Nova Scotia		20[3]	Acidified rivers. Decreased pH in lakes over a 20-30 year period.
Observed at BWCA	15[4,5]	(14)[5]	Stream pH depression of 0.8 units measured.
Observed at Kenora	12[5,6]	(11)[5]	No apparent detrimental effects.
INDICATED MINIMUM EFFECTS FOR LOADING TOLERANCES			
Almer/Dickson model(Fig.49)	≅16		To protect moderately sensitive waters.
" " " "	≅10		To protect the most sensitive waters.
Henriksen Nomograph(Fig.50)		≅20*	To protect lakes above 50 μeq/ℓ cations, i.e. the majority of sensitive lakes.
" " " "		≅12*	To protect the most sensitive waters.
C.D.R. estimate for(Fig.52) Nova Scotia Rivers	≅7		To restore rivers to pH 5.8
" "	≅20		To restore rivers to pH 5.3
pH depression (Table 22) Relationship		≅10	Required to prevent detrimental pH depression in streams and lakes.

* Assuming 1 meter of rain per year, since the model prediction is based on precipitation pH.

[1] Likens *et al*. (1977, 1980); [2] Johannes *et al*. (1981); [3] Harvey *et al*. (1981); [4] Raglund and Wilkening (1981); [5] Glass and Brydges (1981); [6] Glass and Loucks (1980)

TABLE 24

ILLUSTRATIVE DOSE/RESPONSE/TIME RELATIONSHIPS UNDER SELECTED LOADING PATTERNS

Projected Precipitation Quality	Projected Surface Water Quality	Projected Aquatic Effects
1. SO_4 Loading: Natural to 5 kg ha^{-1} yr^{-1} and 85 cm precipitation per year		
Annual average pH: 5.2 to 6.5	Almer/Dickson Relation: Minor pH, aluminum and trace metal changes in very sensitive lakes.	Probably no biotic effects.
Annual average pH 5.0*	Henriksen Nomograph: No expected changes in lake status.	Probably no biotic effects.
	Episode Receptor/Dose: pH depression up to 0.7 units in very sensitive systems; up to 0.25 pH units change in moderately sensitive systems	Possible fish mortality in some years in very sensitive systems if pH depression coincides with sensitive life stages. No biotic effects in moderately sensitive lakes.
2. SO_4 Loading: 15 kg ha^{-1} yr^{-1} and 85 cm precipitation per year		
Annual average pH: 4.6 to 4.8; single episodes to pH 4.2	Almer/Dickson: An average of 1 unit pH change for very sensitive lakas; minor to no pH changes for moderately sensitive lakes.	Fish mortality in very sensitive lakes; no known biotic effects in moderately sensitive lakes.
Annual average pH 4.5*	Henriksen: Ca. 30% of lakes in Norwegian study area would become acidified.	Potential fish mortalities in ca. 30% of lakes in study area due to acid conditions and elevated aluminum concentrations. Shifts in other native populations.
	Episode Receptor/Dose: Ca. 1.0 pH unit depression during episodes in very sensitive streams; near 0.5 pH unit depression in moderately sensitive lakes.	Fish mortality in very sensitive systems if pH depression coincides with sensitive life history stages.

TABLE 24 (Continued)

ILLUSTRATIVE DOSE/RESPONSE/TIME RELATIONSHIPS
UNDER SELECTED LOADING PATTERNS

Projected Precipitation Quality	Projected Surface Water Quality	Projected Aquatic Effects
3. SO_4 Loading: 45 kg ha^{-1} yr^{-1} and 85 cm precipitation per year		
	Almer/Dickson: An average of 1 to 2 unit pH changes for very sensitive lake; 1 unit change for moderately sensitive lakes.	Metal mobilization and elimination of sensitive species from very sensitive lakes; major shifts in populations in very sensitive lakes; partial mortality of sensitive biota in moderately sensitive lakes.
Annual average pH: 4.08*	Henriksen: Approximately 90% of lakes in Norwegian study area appear to become acidified.	Potential fish mortalities in 90% of lakes in study area due to acid conditions and elevated aluminum concentrations; shifts in natural populations; elimination of sensitive biota from most sensitive lakes.
	Episode Receptor/Dose: ca. 1.5 pH unit depression in very sensitive systems; ca. vicinity of 0.6 pH unit depression in slightly sensitive systems.	Elimination of sensitive biota from very sensitive systems; major shifts in natural populations; partial mortalities in moderately sensitive systems due to heavy metal and aluminum mobilization.

* From Henriksen equations (1980).

tions of incomplete data bases and validation steps must be heeded, but there is considerable consistency in the projections. Biological responses range from negligible to significant for the most sensitive streams or lakes, with SO_4 loadings ranging from 5 to 15 kg ha^{-1} yr^{-1}. Effects are less extreme in moderately to only slightly sensitive streams and lakes.

These results indicate that reductions in sulfate deposition of from 50% to 75% are required to protect the most sensitive aquatic systems in the more heavily loaded areas of eastern North America. Furthermore, protection of the aquatic environment should be viewed as a "sliding scale" such that all reductions in sulfate deposition are likely to reduce the number of streams and lakes experiencing damage. The loading targets given here are intended to provide a basis for discussions on whether to protect all but the most sensitive surface waters, or to define some other "acceptable level" of resource alteration. The closer the actual loadings come to the targets, the fewer lakes and streams are likely to be damaged.

RESEARCH AND MONITORING NEEDS

Although some aspects of lake and stream acidification processes are well known, the results reviewed here identify numerous gaps in the information on regional effects and in predictive capabilities as to long-term responses. There is an immediate need in both the United States and Canada for improved knowledge as to the nature of geochemical alterations affecting water quality and the associated biological effects. Considerably more research is needed on modeling the dose/response relationship and on defining target loadings so that the most cost-effective control program can be implemented.

The list of research needs outlined below covers the same major topics as those identified within this aquatic effects report. Since they interrelate, all are considered to be of approximately equal priority for understanding each nation's risks with respect to the aquatic impacts of atmospheric deposition. Some topics may, indeed, have more importance than others when seen from regional or disciplinary perspectives. Following the list of critical research topics, arranged according to the report outline, baseline data needs are described for long-term impact assessment.

Critical Research Topics

The following topic areas represent issues in which there are major information gaps, and which should be addressed by research programs in both the United States and Canada at the earliest possible date.

Element Fluxes and Geochemical Alterations of Watersheds:

Three areas of research are needed here, all requiring relatively intensive study of both terrestrial (geochemical) and aquatic (hydrologic) components, mostly focused around calibrated watersheds of comparable research design and intensive data quality assurance.

1. The four ions of primary concern regarding acidification are hydrogen, ammonium, sulfate and nitrate. Each ion reacts differently with the soil matrix and vegetation. It is necessary, therefore, to define in specific terms the fate and effect on surface water acidification of hydrogen, ammonium, sulfate and nitrate ions originating as atmospheric input.

   Comparison of results from calibrated watersheds with different soil and vegetation conditions is urgently needed. This report indicates that priority may have to be given to sulfur emissions control, drawing heavily on evidence that nitrogen deposition does not contribute significantly to surface water acidification, even though it contributes to precipitation acidity. The long-term necessity for a sulfur control priority needs to be established beyond doubt, as soon as possible, in order to minimize the risk of making costly errors in a control program.

2. Acidic deposition results in mobilization of metals, such as aluminum, iron and manganese, from the soil particles in watersheds. Further work is needed to define the amounts and species of metals leached from watersheds and their biological consequences.

3. There is evidence that groundwater is being acidified and that metal concentrations are elevated in areas where snowmelt gains direct access to sandy subsoils with low acid neutralizing capacity. The effect may be seasonal, with pH values recovering during the summer as neutralization slowly takes place. Further surveys are needed to establish the extent and characteristics of groundwater modification over time and across geographical gradients in acid loadings.

Alterations of Surface Water Quality:

Two major areas of information needs have been identified in the extent and periodicity of surface water quality effects:

1. The geographic extent of surface water acidification is not yet fully documented in North America. Obvious data gaps exist in the central, southern and western United States and in parts of Canada. In addition, reliable data on time-trends in water quality appear to be sparse throughout North America, although some data have not yet been evaluated. Much of the new data needed can be obtained as part of the long-term monitoring program described below. The critical need is to begin long-term water quality measurements in a carefully selected range of aquatic environments as soon as possible.

2. One of the most common manifestations of acidic deposition observed in eastern North America is periodic pH depression in streams and lakes due to snowmelt or heavy rain. Since periodic low pH is a current problem for biological resources, and likely to remain so until acidic deposition is reduced, the quantitative relationship between acidic deposition and short-period pH

depression should be determined for a broad spectrum of aquatic environments. A dose/response relationship for episodic acute exposures to H and aluminum will be a major element in defining acceptable acid loadings.

Alteration of Biotic Components:

Effects on the biological components of aquatic ecosystems appear to be more poorly known than others. Five research topics are identified:

1. It is essential that the biological responses to various water chemistry changes induced by acidic deposition be evaluated in considerable detail to further define dose/response relationships. Studies of dose/response relationships in aquatic ecosystems should include surveys of phytoplankton, macrophytes, zooplankton, benthos and amphibians. Several species among these groups are quite sensitive to changes in pH.

   Of particular importance to the dose/response relationship is quantification of response data for indigenous species that may be vulnerable to low pH or elevated aluminum, and the pH at which effects are expressed. Special attention needs to be given to determining the pH at which species unique to certain areas are harmed and begin to show some failure in reproduction. In addition, community-level attributes of aquatic systems are likely to be sensitive to acid-induced stresses but are difficult to determine; nevertheless they should be understood fully. These include plankton species composition, predator-prey relationships, and trophic-state modification of lakes due to altered nutrient cycles.

2. Damage to fish populations is of particular concern because the loss of fish breaks a major link in the water/terrestrial food chain. Sport fishing is an important industry in most of the areas affected by acidic deposition, and reduction in fish supply could have serious economic consequences. Mechanisms by which low pH and high metal concentrations affect fish should be studied to improve general understanding of the toxicity phenomenon and to improve the ability to predict future effects if acidic deposition continues. Fish sensitivity to H and metal ions should be determined by direct bioassay at different stages in the life cycle, concentrating on reproduction and recruitment. Behavioral or physiological changes (e.g., blood ion levels) known to be affected by sublethal acid and metal concentrations also should be evaluated. Long-term monitoring should include fish population data as well as other measures of biological productivity.

3. Further study is needed to define the biological effects and tolerances for periodic pH depression in streams and lakes. Current work should be extended to include the Great Lakes tributaries draining Precambrian areas. All such potentially sensitive areas in the United States and Canada should be surveyed to determine whether low pH and high metal concentrations

occur, and if so, whether there has been any reduction in spawning success for fish species in those tributaries.

4. Mercury and other metal and combustion-related organic concentrations in fish and other wildlife may be increased by the acidification process or by increased atmospheric emissions, or both. Increased effort should be placed on measuring existing concentrations and time trends throughout the wildlife food chain as a function of lake and stream pH values. Laboratory and field studies are needed to establish the biological significance of various mercury concentrations in indigenous species of fish, birds and mammals.

5. When aquatic or terrestrial productivity, or both, is affected, the effect often is evidenced throughout the entire food chain. Thus, there is reason to believe that acidification will have an adverse effect upon food availability to the higher trophic levels of the food chain, including aquatic birdlife and mammals. The long-term effects of habitat damage on the populations of wildfowl and other wildlife should be better defined and the losses of habitat should be quantified.

Irreversible Impacts:

1. Geochemical and hydrologic principles suggest that the processes of sulfate accumulation and associated acidification of soils and surface waters represent a large-scale titration of available alkaline substances. There is evidence that the capacity of watersheds to provide neutralization of acids may become depleted over long periods. Therefore, further work is needed to define the rate of acidification of surface waters, develop predictive models to quantify watershed capacity to neutralize acid over the long term, and to anticipate recovery following abatement.

   The studies should include measurements on the rates of acidification of lake and stream sediments. The results of such studies are needed to assist in setting acid loading tolerances which will be protective of the aquatic environment in the long term.

Target Loadings and Model Validation:

Much uncertainty remains as to the quantification of sulfate deposition levels ("target loadings") consistent with no further significant degradation of natural resources. Two areas of research are needed:

1. Several relationships based on field environmental data have been used to develop descriptive and predictive models of the acidification process. Almer and Dickson's relationship, the Henricksen nomograph and the episodic receptor/dose relation appear to be potentially useful empirical models that warrant comparative analysis with similar background data bases. Efforts should be made to conduct additional validation of existing and emerging models descriptive of the process of acidification.

2. Relatively detailed simulation models of the acidification process and its effects also are being developed by several research groups. These should be evaluated using watershed data bases from a number of intensive study sites in sensitive areas as identified in this report. If important data are presently missing at these sites, they should be added to the measurement program, or if certain summaries are not being made, these should be added. The need is to have the most complete, quantitative long-term dose/response models evaluated fully and compared with the more empirical field relationships now in use. In support of this validation process, every effort should be made to maximize the use of existing information from all sources.

Relatively intensive studies of material exchanges in watersheds are required to provide such validation, and indeed, many other research needs can be met through site intensive studies. Reasonable validation of the above types of models will require considerable new research, including new, intensive study sites in both the United States and Canada. Study areas for evaluating atmospheric transport models (see Work Group 2 report) should coincide with these detailed studies of soil and water quality alterations in sensitive receptor areas. Locations which already have some data and which should be considered in the development of additional model validation data include:

1. Experimental Lakes Area - Ontario
2. Boundary Waters Canoe Area Wilderness - Minnesota
3. Algoma Area Watershed Study - Ontario
4. Dorset-Haliburton Study Area - Ontario
5. ILWAS Project - New York
6. Laurentide Park (Lac Laflame) - Quebec
7. Kejimkujik Park - Nova Scotia
8. Hubbard Brook - New Hampshire
9. Northern Highlands Lakes - Wisconsin
10. Coweeta - North Carolina

Long-Term Data Collection and Monitoring

The present limited ability of the scientific community to assess critically the extent of impacts from elevated acidity in precipitation, and from other components of atmospheric deposition, is a consequence of few reliable baseline observations on sensitive aquatic environments. This lack of systematic data arises primarily because many studies and monitoring programs were planned to define the influences of local anthropogenic development and are, therefore, located near these influences. Because acidification is of greatest importance in remote areas unaffected by local discharges, very few areas exist with any long-term baseline information.

Filling this information gap as quickly as possible should be a priority in both the United States and Canada. This is needed so that positive, definitive analyses of ecosystem response to the changes in atmospheric deposition can be carried out with extensive verification. Unless a monitoring program is in place and providing a documented time-series of system properties, there will be no significant capacity to quantify the results of either emission reductions or increases.

While a variety of data needs have been implicit throughout this aquatic effects report, certain classes of long-term measurements are needed at selected sites. Included are the following four:

1. Since a major component of aquatic research is the calibrated watershed, long-term studies of these systems should be intensified with the general objective of improving the estimates of rates of changes in water quality and biological effects relative to acid loadings (i.e., dose/response relationships), improving the understanding of the relative influence of sulfur and nitrogen loading, and establishing better measures of lake sensitivity so the present and potential extent of the problem can be more clearly defined.

2. Analyses should be undertaken of all available baseline studies (particularly in the United States) including regional monitoring of surface water quality, plankton, fauna, soil, and vegetation records.

3. Criteria for selection of streams and lakes for new monitoring of water quality and biota should include factors related to alkalinity sources, lake morphometry, watershed morphometry, ground water inputs, vegetation cover (i.e., age of forest and community structure), surface water chemistry, ground water chemistry, and type of biotic community (cold water, warm water, etc.). The regions and lakes chosen for analysis should range from very sensitive through moderately sensitive to "tolerant" (reference lakes), although a geographic grid of comparable sites also should be developed. Data collected should include chemical and biological parameters identified as susceptible to change.

4. Experimental manipulations should be carried out using adjacent watersheds with small lakes. Watershed-level experiments should include "simulated acid precipitation" additions of H, SO_4, NH_4, NO_3, etc., so that long term recovery following termination of acid additions can be investigated.

REFERENCES

Abrahamsen, G. 1980. Acid precipitation, plant nutrients and forest growth. pp. 58-63. In D. Drabløs and A. Tollan (eds.) Ecological Impact of Acid Precipitation. Proceedings of an international conference, Sandefjord, Norway, March 11-14, 1980. SNSF Project, Norway, 1980.

Abrahamsen, G., K. Bjor, R. Horntvedt and B. Tveite. 1976. Effects of acid precipitation on coniferous forest. pp. 36-63. In F.H. Braekke (ed.) Impact of Acid Precipitation on Forest and Freshwater Ecosystems in Norway. SNSF-Project, NISK, 1432 Aas-NLH, Norway.

Abrahamsen, G., R. Hornvedt, and B. Tveite. 1977. Impacts of acid precipitation on coniferous forest ecosystems. Water Air Soil Pollut. (8):57-73.

Almer, B., W. Dickson, C. Ekström, and E. Hornström. 1978. Sulfur pollution and the aquatic ecosystem. pp. 271-311. In J.O. Nriagu (ed.). Sulfur in the Environment. Part II. Ecological Impacts. J. Wiley and Sons, Inc., New York, N.Y.

Altshuller, A.P., and G.A. McBean. 1980. Second Report of the U.S.-Canada Research Consultation Group on Long Range Transport of Air Pollutants, November 1980, 40 pp (Avail. from Environ. Can. Ottawa).

Andren, A. 1981. Personal communication. Water Chemistry Department, University of Wisconsin, Madison, Wisconsin.

Andrews, L.M., and C.W. Threinen. 1966. Surface water resources of Oneida County. Wisconsin Conservation Dept. Report. Madison, Wisconsin.

Andrews, R.D. 1975. Tailings: Environmental consequences and a review of control strategies. pp. 645-675. In T.C. Hutchinson (ed.) International Conference on Heavy Metals in the Environment, Toronto, Ontario, Canada, October 27-31, 1975. National Research Council of Canada, Ottawa, Ontario, Canada.

Arnold, D.E. 1981. Vulnerability of lakes and streams in the middle Atlantic states to acidification. Interim Progress Report. Cooperative Fisheries Research Unit, Pennsylvania State University, University Park, Pennsylvania.

Baker, J.P. 1981. Aluminum toxicity to fish as related to acid precipitation and Adirondack surface water quality. Ph.D. Thesis. Cornell University, Ithaca, New York. 441 pp.

Baker, J.P. 1981. Personal communication. Cornell University, Ithaca, New York.

Baker, J.P., and C.L. Schofield. 1980. Aluminum toxicity to fish as related to acid precipitation and Adirondack surface water quality. pp. 292-293. In D. Drabløs and A. Tollan (eds.) Ecological Impact of Acid Precipitation. Proceedings of an international conference, Sandefjord, Norway, March 11-14, 1980. SNSF Project, Norway, 1980.

Barrie, L.A. 1981. Environment Canada's long range transport of atmospheric pollutants program: Atmospheric Studies. In Proceedings of the Conference on The Effects of Acid Precipitation on Ecological Systems (supplement), April 1-3, 1981. Michigan State University, East Lansing, Michigan.

Bauer, C., K. Vern Mark, B. Price, and A.W. Andren. 1982a. Organic Vapor Emissions from a Coal-fired Steam Plant. Final Report in preparation to the U.S. Environmental Protection Agency. University of Wisconsin, Madison, Wisconsin.

Bauer, C., A.W. Andren, and M. Knaebe. 1982b. Chemical Composition of Particulate Emissions from a Coal-Fired Steam Plant: Variation as a Function of Time and Size. Final Report in preparation to the U.S. Environmental Protection Agency. University of Wisconsin, Madison, Wisconsin.

Beamish, R.J. 1974a. The loss of fish populations from unexploited remote lakes in Ontario, Canada as a consequence of atmospheric fallout of acid. Water Res. 8:85-95.

Beamish, R.J. 1974b. Growth and survival of white suckers (Catostomus commersoni) in an acidified lake. J. Fish. Res. Board Can. 31:49-54.

Beamish, R.J. 1976. Acidification of lakes in Canada by acid precipitation and the resulting effects on fishes. Water Air Soil Pollut. 6:501-514.

Beamish, R.J., L.M. Blouw, and G.A. McFarlane. 1976. A fish and chemical study of 109 lakes in the Experimental Lakes Area (ELA), Northwestern Ontario, with appended reports on lake whitefish aging errors and the Northwestern Ontario baitfish industry. Environ. Canada, Fish and Mar. Service, Tech. Rep. No. 607.

Beamish, R.J., and H.H. Harvey. 1972. Acidification of the La Cloche Mountain lakes, Ontario and resulting fish mortalities. J. Fish. Res. Board Can. 29:1131-1143.

Beamish, R.J., W.L. Lockhart, J.C. VanLoon, and H.H. Harvey. 1975. Long term acidification of a lake and resulting effects on fishes. Ambio 4:98-102.

Beebee, T.J.C., and J.R. Griffin. 1977. A preliminary investigation into Natterjack toad (Bufo calamita) breeding site characteristics in Britain. J. Zool. London 181:341-350.

Beggs, G. 1981. Personal communication. Ontario Ministry of Natural Resources. Ottawa, Ontario, Canada.

Bell, H.L. 1971. Effects of low pH on the survival and emergence of aquatic insects. Water Res. 5:313-319.

Bick, H., and E.F. Drews. 1973. Self purification and silicate communities in an acid milieu (model experiments). Hydrobiologia 42:393-402.

Billings, C.E., and W.R. Mattson. 1972. Mercury emissions from coal combustion. Science 176:1232-1233.

Bisogni, J.J., Jr., and C.T. Driscoll. 1979. Characterization of the pH buffering systems in dilute Adirondack surface waters. Office of Water Research and Tech., project A-073-NY.

Bisogni, J.J., Jr., and A.W. Lawrence. 1973. Kinetics of microbially medicated methylation of mercury in aerobic and anaerobic aquatic environments. Cornell Univ. Tech. Rep. 63, Ithaca, N.Y.

Bormann, F.H., and G.E. Likens. 1979. Pattern and Process in a Forested Ecosystem: Disturbance, development and the steady state based on the Hubbard Brook ecosystem study. Springer-Verlag, New York. 253 pp.

Brewer, P.G., and J.C. Goldman. 1976. Alkalinity changes generated by phytoplankton growth. Limnol. Oceanogr. 21:108-117.

Brouzes, R.J.P., R.A.N. McLean, and G.H. Tomlinson. 1977. Mercury - The Link Between pH of Natural Waters and the Mercury Content in Fish. Res. Rep. Domtar Ltd., Research Center, Montreal, Quebec. 37 pp.

Bryson, R.A., and F.K. Hare. 1974. In H. Landsberg (ed.) World Surveys of Climatology. Vol. VII. The Climates of North America. Elsevier Press. 432 pp.

Burton, T.M., and G.E. Likens. 1975a. Energy flow and nutrient cycling in salamander populations in the Hubbard Brook Experimental Forest, New Hampshire. Ecology 56:1068-1080.

Burton, T.M., and G.E. Likens. 1975b. Salamander populations and biomass in the Hubbard Brook Experimental Forest, New Hampshire. Copeia 1975(3):541-546.

Cawse, P.A. 1974. A survey of atmospheric trace elements in the United Kingdom. A.E.R.E. Hawwell Report No. R-7669, HMSO, London.

Cecil, S.G., and J.J. Just. 1979. Survival rate, population density and development of naturally occurring anuran larvae (*Rana catesbiana*). Copeia 1979(3):447-452.

Chamberlain, A.C. 1966. Transport of gases to and from grass and grass-like surfaces. Proc. Roy. Soc. London A296:45-70.

Chan, W.H., R.J. Vet, M.A. Lusis, J.E. Hunt, and R.D.S. Stevens. 1980. Airborne sulfur dioxide to sulfate oxidations studies of the INCO 381m chimney plume. Atmos. Environ. 14:1159-1170.

Charette, J.-Y., and M. Lagacé. 1981. Recherche d'ne methodologie et evaluation de l'impact des precipitations acedis su la faune pisicole du Parc Des Laurentide. Quebec Ministry of Environ. and Quebec Ministry of Recreation, Hunting and Fishing, Quebec, Canada.

Christophersen, N., and R.F. Wright. 1980. Sulphate at Birkenes, a small forested catchment in southernmost Norway. pp. 286-287. *In* D.Drabløs and A. Tollan (eds.) Ecological Impact of Acid Precipitation. Proceedings of an international conference, Sandefjord, Norway, March 11-14, 1980. SNSF Project, Norway, 1980.

Clair, T.A. 1981. LRTAP sensitivity sampling of Labrador-1980. Environment Canada, Water Quality Branch, Atlantic Region. Moncton, N.B., Canada.

Clair, T.A. 1981. Personal communication. Environment Canada, Water Quality Branch, Atlantic Region. Moncton, N.B., Canada.

Clair, T.A., J.P. Witteman, T.L. Pollock, and S. Whitlow. 1979. Sensitivity of the Maritime Provinces to acid precipitation: A preliminary report. Manuscript report, Environment Canada, Water Quality Branch, Moncton, N.B., Canada. 7 pp.

Clark, K., and D. Euler. 1980. Reptile and amphibian habitat and human activity in central Ontario. Tech. Rep. Phase III, Lakeshore Capacity Study. 28 pp.

Clark, K., and K. Fischer. 1981. Acid precipitation and wildlife. Can. Wildlife Serv., Wildlife Toxicology Series #34.

Clymo, R.S. 1963. Ion exchange in *Sphagnum* and its relation to bog ecology. Ann. Bot. 27(106):309-324.

Cook, R.P. 1978. Effects of acid precipitation on embryonic mortality of the spotted salamander, *Ambystoma maculatum*, and Jefferson salamander, *Ambystoma jeffersonianum*, in the Connecticut Valley of Massachussetts. MSc. thesis, U. of Massachusetts, Amherst, Mass.

Cooke, A.S., and J.F.P. Frazer. 1976. Characteristics of newt breeding sites. J. Zool. London 178:223-236.

Craig, G.R., and W.F. Baksi. 1977. The effects of depressed pH on flagfish reproduction, growth and survival. Water Res. 11:621-626.

Crisman, T.L., and P.L. Brezonik. 1980. Paper for presentation to 73rd Annual Meeting Air Pollut. Contr. Assoc., Montreal, Quebec, Canada.

Cronan, C.S., and C.L. Schofield. 1979. Aluminum leaching response to acid precipitation: Effects on high-elevation watersheds in the northeast. Science 204:304-306.

Crum, H. 1976. Mosses of the Great Lakes Forest. University Herbarium, University of Michigan, Ann Arbor, Michigan. 404 pp.

Davis, J.M. 1980. External Review Draft. U.S. Environ. Crit. and Assess. Off., Research Triangle Park, North Carolina. 91 pp.

Daye, P.G. 1980a. Attempts to acclimate embryos and alevins of Atlantic salmon, Salmo salar, and rainbow trout, S. gairdneri, to low pH. Can. J. Aquat. Sci. 37:1035-1038.

Daye, P.G. 1980b. Effects of ambient pH on fish: An annotated bibliography. Can. Tech. Rep. Fish. and Aquat. Sci. No. 950, St. Andrews, N.B., Canada. 28 pp.

Daye, P.G., and E.T. Garside. 1975. Lethal levels of pH for brook trout, Salvelinus fontinalis (Mitchill). Can. J. Zool. 53:639-641.

Daye, P.G., and E.T. Garside. 1977. Lower lethal levels of pH for embryos and alevins of Atlantic salmon, Salmo salar. Can. J. Zool. 55:1504-1508.

Daye, P.G., and E.T. Garside. 1980a. Structured alterations in embryos and alevins of the Atlantic salmon, Salmo salar L., induced by continuous or short-term exposure to acidic levels of pH. Can. J. Zool. 58:27-43.

Daye, P.G., and E.T. Garside. 1980b. Development, survival and structural alterations of embryos and alevins of Atlantic salmon, Salmo salar L., continuously exposed to alkaline levels of pH, from fertilization. Can. J. Zool. 58:369-377.

DeBenedictis, P.A. 1974. Interspecific competition between tadpoles of Rana pipiens and Rana sylvatica: An experimental field study. Ecol. Monogr. 44:129-151.

Dickson, W. 1975. The acidification of Swedish lakes. Institute of Freshwater Research. Rep. No. 54:8-20. Drottningholm, Sweden.

Dickson, W. 1978. Some effects of the acidification of Swedish lakes. Verh. Int. Verein. Limnol. 20:851-856.

Dickson, W., E. Hornström, C. Ekström, and B. Almer. 1975. Rodingsjoar soder OmDalalben. Information fran Drottningholm 7, Sweden. 140 pp.

Dillon, P.J., D.S. Jeffries, W.A. Scheider, and N.D. Yan. 1980. Some aspects of acidification in southern Ontario. pp. 212-213. In D.Drabløs and A. Tollan (eds.) Ecological Impact of Acid Precipitation. Proceedings of an international conference, Sandefjord, Norway, March 11-14, 1980. SNSF Project, Norway, 1980.

Dillon, P.J., D.S. Jeffries, W. Snyder, R. Reid, N.D. Yan, D. Evans, J. Moss and W.A. Scheider. 1978. Acid precipitation in south-central Ontario: Recent observations. J. Fish. Res. Board Can. 35:809-815.

Dillon, P.J., and F.H. Rigler. 1975. A simple method for predicting the capacity of a lake for development based on lake trophic status. J. Fish. Res. Board Can. 32:1519-1531.

Dillon, P.J., N.D. Yan, W.A. Scheider and N. Conroy. 1979. Acidic lakes in Ontario, Canada: Characterization, extent and responses to base and nutrient additions. Arch. Hydro. Beih. Ergebn. Limnol 13:317-336.

Doudoroff, P., and M. Katz. 1950. Critical review of literature on the toxicity of industrial wastes and their components to fish. I. Alkalies, acids and inorganic gases. Sewage Ind. Wastes 22:1432-1458.

Drabløs, A., I. Sevaldrud, and J.A. Timberlid. 1980. Historical land use changes related to fish status development in different areas in southern Norway. pp. 367-369. In D.Drabløs and A. Tollan (eds.) Ecological Impact of Acid Precipitation. Proceedings of an international conference, Sandefjord, Norway, March 11-14, 1980. SNSF Project, Norway, 1980.

Driscoll, C.T. 1980. Aqueous speciation of aluminum in the Adirondack region of New York State, U.S.A. pp. 214-215. In D.Drabløs and A. Tollan (eds.) Ecological Impact of Acid Precipitation. Proceedings of an international conference, Sandefjord, Norway, March 11-14, 1980. SNSF Project, Norway, 1980.

Driscoll, C.T, J.P. Baker, J.J. Bisogni and C.L. Schofield. 1980. Effect of aluminum speciation on fish in dilute acidified waters. Nature 284:161-164.

Dunshie, D. 1979. USDA/Forest Service Final Report, Monongahela Nat. For., August 1979. Unpublished manuscript, Eastern Region USDA/FS. Milwaukee, Wisconsin. 48 pp.

Duthie, H.C., and M.L. Ostrofsky. 1974. Plankton, chemistry and physics of lakes in the Churchill Falls region of Labrador. J. Fish. Res. Board Can. 31:1105-1117.

EIFAC (European Inland Fisheries Advisory Commission). 1969. Water quality criteria for European freshwater fish. Report on extreme pH values and inland fisheries. Water Res. 3:593-611.

Eilers, J.M., *et al*. 1979. Acid precipitation investigation for northern Wisconsin. Progress Report. Wisconsin DNR, Rhinelander; and U.S. EPA-ERL, Duluth, Minnesota.

Eilers, J.M., and R.G. Berg. 1981. Sensitivity of aquatic organisms to acidic environments. EPA report draft, Environmental Research Lab., Duluth, Minnesota.

Elder, F.C. 1980. Personal communication. Environment Canada National Water Research Institute, Burlington, Ontario, Canada.

Environment Canada. 1981. Sensitivity of Quebec lakes to acidification. Environ. Can., Quebec Region, Ste. Foy, Quebec, Canada.

EPRI. 1980. Inventory of organic emissions from fossil fuel combustion for power generation. EPRI Report EA-1394, 1980. Electric Power Research Institute, 3412 Hillview Avenue, Palo Alto, CA 94304.

Eriksson, M.O.G., L. Henrikson, B.I. Nilsson, G. Nyman, H.G. Oscarson, A.E. Stenson, and K. Larsson. 1980. Predator-prey relations important for the biotic changes in acidified lakes. Ambio 9:248-249.

Everhart, W.H., and R.A. Freeman. 1973. Toxic effects of aqueous aluminum to rainbow trout. EPA-R3-73-011. 41 pp.

Falk, D.L., and W.A. Dunson. 1977. The effects of season and acute sublethal exposure on survival times of brook trout at low pH. Water Res. 11:13-15.

Farmer, G.J., T.T. Goff, D. Ashfield, and H.S. Samant. 1980. Some effects of the acidification of Atlantic salmon rivers in Nova Scotia. Can. Fish. and Aquat. Sci. Tech. Rep. No. 972, 13 pp.

Feller, M.C. 1975. Initial effects of clearcutting on the flow of chemicals through a forest-watershed ecosystem. Ph.D. Thesis, Faculty of Forestry, University of British Columbia, Vancouver, B.C., Canada. 352 pp.

Feller, M.C. 1977. Nutrient movement through western hemlock-western red-cedar ecosystems in southwestern British Columbia. Ecology 58:1269-1283.

Fiance, S.B. 1978. Effects of pH on the biology and distribution of *Ephemerella funeralis* (*Ephemeroptera*). Oikos 31:332-339.

Fowler, D. 1980. Removal of sulphur and nitrogen compounds from the atmosphere in rain and by dry deposition. pp. 22-32. *In* D. Drabløs and A. Tollan (eds.) Ecological Impact of Acid Precipitation. Proceedings of an international conference, Sandefjord, Norway, March 11-14, 1980. SNSF Project, Norway, 1980.

Fromm, P.O. 1980. A review of some physiological and toxicological responses of freshwater fish to acid stress. Environ. Biol. Fish. 5:79-93.

Galloway, J.N., and E.B. Cowling. 1978. The effects of precipitation on aquatic and terrestrial ecosystems - A proposed precipitation chemistry network. J. Air Pollut. Contr. Ass. 28:229-235.

Galloway, J.N., C.L. Schofield, G.R. Hendry, N.E. Peters and A.H. Johnnes. 1980. Sources of acidity in three lakes acidified during snow melt. pp. 264-265. In D.Drabløs and A. Tollan (eds.) Ecological Impact of Acid Precipitation. Proceedings of an international conference, Sandefjord, Norway, March 11-14, 1980. SNSF Project, Norway, 1980.

Galloway, J.N., and D.M. Whelpdale. 1980. An atmospheric sulfur budget for eastern North America. Atmos. Environ. 14:409-417.

Garland, J.A. 1979. Dry deposition of gaseous pollutants. pp. 95-103. In Proceedings of the WMO Symposium on the Long-range Transport of Pollutants and Its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, WMO (Geneva) No. 538.

Gatz, D.F. 1974. Scavenging ratio measurements in METROMEX. p. 43. In Proceedings of a Symposium: Precipitation Scavenging, Champagne, Illinois.

Glass, G.E. 1980. Susceptibility of aquatic and terrestrial resources of Minnesota, Wisconsin and Michigan to impacts from acid precipitation: Informational requirements. pp. 112-113. In D.Drabløs and A. Tollan (eds.) Ecological Impact of Acid Precipitation. Proceedings of an international conference, Sandefjord, Norway, March 11-14, 1980. SNSF Project, Norway, 1980.

Glass, G.E., and T.G. Brydges. 1981. Problem complexity in predicting impacts from altered precipitation chemistry. Intl. Conf. on Acid Precip. Impacts, Cornell Univ., Ithaca, New York, August 1-4, 1981.

Glass, G.E., and O.L. Loucks, eds. 1980. Impacts of airborne pollutants on wilderness areas along the Minnesota-Ontario border. EPA-600/3-80-044. U.S. EPA Environmental Research Lab., Duluth, Minnesota.

Goldberg, E.D., and K. Bertine. 1971. Fossil fuel combustion and the major geochemical cycle. Science 173:233-235.

Gosner, K.L., and I.H. Black. 1957. The effects of acidity on the development and hatching of New Jersey frogs. Ecology 38:256-262.

Grahn, O.H., H. Hultberg, and L. Landner. 1974. Oligotrophication - a self-accelerating process in lakes subjected to excessive supply of acid substances. Ambio 3:93-94.

Granat, L., H. Rodhe, and R.O. Hallberg. 1976. The global sulphur cycle. pp. 89-134. In Svensson and Söderlund (eds.) Nitrogen, Phosphorus, and Sulphur-Global Cycles. Scope Report 7. Ecol. Bull. (Stockholm) 22.

Guthrie, R.K., D.S. Cherry, and F.L. Singleton. 1978. Responses of heterotrophic bacterial populations to pH changes in coal ash effluent. Water Resour. Bull. 14:803-808.

Haines, T.A. 1981a. Effects of acid rain on Atlantic salmon rivers and restoration efforts in the United States. In Proceedings of the Conference on Acid Rain and the Atlantic Salmon, Portland, Maine, November 22-23, 1980. International Atlantic Salmon Foundation Special Publication Series No. 10, March 1981. IASF, New York.

Haines, T.A. 1981b. Vulnerability of lakes and streams in the northeastern U.S. to acidification. Interim Progress Report. Columbia National Fisheries Research Laboratory, U.S. Fish and Wildlife Service, Columbia, Missouri.

Hakanson, L. 1980. The quantitative impact of pH, bioproduction and Hg-contamination on the Hg-content of fish (pike). Environ. Pollut. 1:285-304.

Hall, R.J., and G.E. Likens. 1980. Ecological effects of experimental acidification on a stream ecosystem. pp. 375-376. In D.Drabløs and A. Tollan (eds.) Ecological Impact of Acid Precipitation. Proceedings of an international conference, Sandefjord, Norway, March 11-14, 1980. SNSF Project, Norway, 1980.

Hall, R.J., G.E. Likens, S.B. Fiance and G.R. Hendry. 1980. Experimental acidification of a stream in the Hubbard Brook Experimental Forest, New Hampshire. Ecology 61(4):976-989.

Harvey, H.H. 1975. Fish populations in a large group of acid-stressed lakes. Verh. Internat. Verein. Limnol. 19:2406-2417.

Harvey, H.H. 1979. The acid deposition problem and emerging research needs in the toxicology of fishes. pp. 115-128. In Proc. 5th Annual Aquatic Toxicity Workshop, Hamilton, Ontario, Canada, November 7-9, 1978. Environ. Canada Fish. Mar. Serv. Tech. Rep. 862.

Harvey, H.H. 1980. Widespread and diverse changes in the biota of North American lakes and rivers coincide with acidification. pp. 93-98. In D.Drabløs and A. Tollan (eds.) Ecological Impact of Acid Precipitation. Proceedings of an international conference, Sandefjord, Norway, March 11-14, 1980. SNSF Project, Norway, 1980.

Harvey, H.H. 1981. Central report to the Ontario Ministry of the Environment, Toronto, Ontario, Canada.

Harvey, H.H., R.C. Pierce, P.J. Dillon, J.P. Kramer and D.M. Whelpdale. 1981. Acidification in the Canadian Aquatic Environment: Scientific Criterion for an Assessment of the Effects of Acidic Deposition on Aquatic Ecosystems. Nat. Res. Coun. Canada Report No. 18475.

Havas, M. 1980. A study of the chemistry and biota of acid and alkaline ponds at the Smoking Hills, NWT. Ph.D. thesis, University of Toronto, Toronto, Ontario, Canada.

Hayes, F.R., and E.H. Anthony. 1958. Lake water and sediment. I. Characteristics and water chemistry of some Canadian east coast lakes. Limnol. Oceanogr. 3:299-307.

Henderson, G.S., W.T. Swank, and J.W. Hornback. 1980. Impact of sulfur deposition on the quality of water from forested watersheds. pp. 431-442. In D.S. Shriner, C.R. Richmond, and S.E. Lindberg (eds.) Atmospheric Sulfur Deposition: Environmental Impact and Health Effects. Ann Arbor Sci., Ann Arbor, Michigan.

Hendrey, G.R., K. Baalsrud, T. Traaen, M. Laake, and G. Raddum. 1976. Acid precipitation: Some hydrobiological changes. Ambio 5:224-227.

Hendrey, G.R., J.N. Galloway, S.A. Norton, C.L. Schofield, P.W. Shaffer, and D.A. Burns. 1980. Geological and hydrochemical sensitivity of the eastern United States to acid precipitation. EPA-600/3-80-024. U.S. EPA Environmental Research Lab., Corvallis, Oregon.

Hendrey, G.R., and F. Vertucci. 1980. Benthic plant communities in acidic Lake Colden, New York: Sphagnum and the algal mat. pp. 314-315. In D.Drabløs and A. Tollan (eds.) Ecological Impact of Acid Precipitation. Proceedings of an international conference, Sandefjord, Norway, Ma[illegible]-14, 1980. SNSF Project, Norway, 1980.

Hendrey, G.R., and R.F. Wright. 1976. Acid precipitation in Norway: Effects on aquatic fauna. pp. 192-207 In Proc. 1st Spec. Symp. on Atmospheric Contribution to the Chemistry of Lake Waters. Int. Assoc. Great Lakes Res., Orillia, Ontario, Canada, 28 Sept. - 1 Oct., 1975. J. Great Lakes Res. 2, Suppl. 1.

Henriksen, A. 1979. A simple approach for identifying and measuring acidification of freshwater. Nature 278:542-545.

Henriksen, A. 1980. Acidification of freshwaters - a large scale titration. pp. 68-74. In D.Drabløs and A. Tollan (eds.) Ecological Impact of Acid Precipitation. Proceedings of an international conference, Sandefjord, Norway, March 11-14, 1980. SNSF Project, Norway, 1980.

Herman, F.S., and E. Gorham. 1957. Total mineral material, acidity sulfur and nitrogen in rain and snow in Kentville, Nova Scotia. Tellus 9:180-183.

Herrmann, R., and J. Baron. 1980. Aluminum mobilization in acid stream environments, Great Smoky Mountains National Park, U.S.A. pp. 218-219. In D.Drabløs and A. Tollan (eds.) Ecological Impact of Acid Precipitation. Proceedings of an international conference, Sandefjord, Norway, March 11-14, 1980. SNSF Project, Norway, 1980.

Hicks, B.B., and R.M. Williams. 1980. Transfer and deposition of particles to water surfaces. pp. 237-245 In D.S. Shriner, C.R. Richmond, and S.E. Lindberg (eds.) Atmospheric Sulfur Deposition: Environmental Impact and Health Effects. Ann Arbor Sci., Ann Arbor, Michigan.

Huckabee, J.W., C.P. Goodyear, and R.D. Jones. 1975. Acid rock in the Great Smokies: Unanticipated impact on aquatic biota of road construction in regions of sulfide mineralization. Trans. Amer. Fish. Soc. 104(4):677-684.

Hultberg, H. 1976. Thermally stratified acid water in late winter - a key factor inducing self-accelerating processes which increase acidification. Water Air Soil Pollut. 7:279-294.

Hultberg, H., and O. Grahn. 1976. Effects of acid precipitation on macrophytes in oligotrophic Swedish lakes. pp. 208-221 In Proc. First Specialty Symposium on Atmospheric Contribution to the Chemistry of Lake Waters. Internat. Assoc. Great Lakes Res., Sept. 28 - Oct. 1, 1975.

Hutchison, T.C., W. Gizyn, M. Havas, and V. Zobens. 1978. Effect of long-term lignite burns on Arctic ecosystems at the Smoking Hills, N.W.T. pp. 317-332. In D. Hemphill (ed.) Trace Substances in Environmental Health. University of Missouri, Columbia, Missouri.

Jeffries, D.S., C.M. Cox, and P.J. Dillon. 1979. Depression of pH in lakes and streams in central Ontario during snowmelt. J. Fish. Res. Board Can. 36:640-646.

Jeffries, D.S., and A.P. Zimmerman. 1980. Comments on the analysis and sampling of low conductivity natural waters from alkalinity. Can. J. Fisheries Aquat. Sci. 37:901.

Jensen, K.W., and E. Snekvik. 1972. Low pH levels wipe out salmon and trout populations in southern Norway. Ambio 1:223-225.

Jernelov, A., C. Hansson, and L. Linse. 1976. An investigation of an effect of pH and total phosphorus on the measured variation of mercury in Varmland. Institute for Water and Air Pollution Research (IVL), B282, Stockholm, Sweden, 10 pp.

Johannes, A.H., and E.R. Altwicker. 1980. Atmospheric inputs to three Adirondack lake watersheds. pp. 256-257. In D.Drabløs and A. Tollan (eds.) Ecological Impact of Acid Precipitation. Proceedings of an international conference, Sandefjord, Norway, March 11-14, 1980. SNSF Project, Norway, 1980.

Johannes, A.H., E.R. Altwicker, and N.L. Clesceri. 1981. Characterization of Acidic Precipitation in the Adirondack Region. EPRI EA-1826, Project 1155-1, Final Report by Rensselaer Poiytechnic Institute, Troy, New York, for Electric Power Research Institute, Palo Alto, California.

Johannessen, M. 1980. Aluminum, a buffer in acidic waters? pp. 222-223. In D.Drabløs and A. Tollan (eds.) Ecological Impact of Acid Precipitation. Proceedings of an international conference, Sandefjord, Norway, March 11-14, 1980. SNSF Project, Norway, 1980.

Johnson, A.H. 1979. Evidence of acidification of headwater streams in the New Jersey pinelands. Science 206:834-836.

Johnson, D.W. 1980. Site susceptibility to leaching by H_2SO_4 in acid rainfall. pp. 525-536. In T.C. Hutchinson and M. Havas (eds.) Effects of Acid Precipitation on Terrestrial Ecosystems. Plenum Press, New York. 654 pp.

Johnson, D.W. 1981. Personal communication. Oak Ridge National Laboratory. Oak Ridge, Tennessee.

Johnson, D.W., J.W. Hornbeck, J.M. Kelly, W.T. Swank, and D.E. Todd. 1980. Regional patterns of soil sulfate accumulation: Relevance to ecosystem sulfur budgets. pp. 507-520. In D.S. Shriner, C.R. Richmond and S.E. Lindberg (eds.) Atmospheric Sulfur Deposition: Environmental Impact and Health Effects. Ann Arbor Science, Ann Arbor, Michigan. 568 pp.

Juang, A.J., and N.M. Johnson. 1967. Cycling of chlorine through a forested catchment in New England. J. Geophys. Res. 1972:5641-5647.

Junge, C.E. 1972. The cycle of atmospheric gases - natural and manmade. Quart. J. Royal Meterological Soc. 98:711-729.

Junge, C.E. 1974. Residence time and variability of tropospheric trace gases. Tellus 26:477-488.

Junge, C.E. 1977. Basic considerations about trace constituents in the atmosphere as related to the fate of global pollutants. In I.H. Suffet (ed.) Fate of Pollutants in the Air and Water Environments, Part I. J. Wiley and Sons, N.Y.

Jurkovic, A.A., and P. Robson. 1981. Effects of acid precipitation on microbial populations in northern Ontario lakes. Manuscript report, National Water Research Institute, Canada Center for Inland Waters, Burlington, Ontario, Canada. 18 pp.

Kellogg, W.W., R.D. Cadle, E.R. Allen, A.L. Lazrus, and E.A. Martell. 1972. The sulfur cycle. Science 175 (4022):587-596.

Kerekes, J.J. 1980. Preliminary characterization of three lake basins sensitive to acid precipitation in Nova Scotia, Canada. pp. 232-233. In D.Drabløs and A. Tollan (eds.) Ecological Impact of Acid Precipitation. Proceedings of an international conference, Sandefjord, Norway, March 11-14, 1980. SNSF Project, Norway, 1980.

Kerekes, J.J. 1981. Summary of the 1980 Environmental Contaminants Control Fund investigation in the calibrated watersheds study in Kejimkujik National Park. Unpublished Manuscript, Canadian Wildlife Service, Halifax, Nova Scotia, Canada.

Klein, D.H., A.W. Andren, and N.E. Bolten. 1975. Trace element discharges from coal combustion for power production. Water Air Soil Pollut. 5:71-77.

Klein, D.H., A.W. Andren, J.A. Carter, J.F. Emery, C. Feldman, W. Fulkerson, W.S. Lyon, J. Ogle, Y. Palmi, R.I. Van Hook, and N. Bolton. 1975. Pathways of 37 trace elements through a coal-fired powerplant. E S & T 9:973-979.

Klick, T.A., and C.W. Threinen. 1968. Surface Water Resources of Jackson County. Wisconsin Dept. Natural Resources, Madison, Wisconsin.

Kramer, J.R. 1976. Geochemical and lithological factors in acid precipitation. U.S.D.A. Forest Service Gen. Tech. Rep. NE-23. pp. 611-618.

Kramer, J.R. 1979. Susceptible areas in Ontario and Quebec. In Geochemical Factors and Terrain Response to Environmental Contaminants. Report to Inland Waters Directorate, June 1979. 78 pp.

Kramer, J.R. 1980. Precise determination of low alkalinities using the modified Gran analysis. An inexpensive field procedure. Environmental Geochemistry Report 1980/1, Department of Geology, McMaster University, Hamilton, Ontario. 11 pp.

Kwain, W.H. 1975. Effects of temperature on development and survival of rainbow trout, *Salmo gairdneri*, in acid waters. J. Fish. Res. Board Can. 32:493-497.

Kwiatkowski, R.E., and J.C. Roff. 1976. Effects of acidity on phytoplankton and primary production of selected northern Ontario lakes. Can. J. Bot. 54:2546-2561.

Laake, M. 1976. Effects of low pH on some biological processes in natural and artificial lake sediments. SNSF IR 29/76, NISK 1432 Aas-NLH, Norway. 75 pp.

Landner, L., and P.O. Larsson. 1972. Biological effects of mercury fallout into lakes from the atmosphere. IVL Report B 115, Swedish Institute for Water and Air Pollution Research, Stockholm. (Translation available from Domtar Research Center.)

Legendre, P, A. Chodorowski, W. Chodorowski, P. Pichet and P. Potvin. 1980. Qualité des Eaux: Interpretations des données lacustres (1971-1977). Ministére de L'environnement du Québec, Service de la Qualité QE-45.

Leivestad, H., G. Hendrey, I.P. Muniz, and E. Snekvik. 1976. Effects of acid precipitation on freshwater organisms. pp. 87-111. In F. Braekke (ed.) Impact of Acid Precipitation on Forest and Freshwater Ecosystems in Norway. SNSF Project, NISK 1432 Aas-NLH, Norway.

Leivestad, H., and I.P. Muniz. 1976. Fish kill at low pH in a Norwegian river. Nature Lond. 259:391-392.

Lemieux, R. 1980. Personal communication. Environment Canada, Quebec Region, Quebec, Canada.

Lewis, W.M., Jr., and M.C. Grant. 1980. Acid precipitation in the Western United States. Science 207:176-177.

Liaw, W.K., and F.M. Alton. 1981. Sensitivity of aquatic ecosystems in Northern Saskatchewan to acidification. Sask. Fish. Lab. Tech. Rep. 81-1. Saskatchewan, Canada. 58 pp.

Likens, G.E., F.H. Bormann, and J.S. Eaton. 1980. Variations in precipitation and streamwater chemistry at the Hubbard Brook Experimental Forest during 1964 to 1977. pp. 443-464 In T.C. Hutchinson and M. Havas (eds.) Effects of Acid Precipitation on Terrestrial Ecosystems. Plenum Press, New York.

Likens, G.E., F.H. Bormann, R.S. Pierce, J.S. Eaton, and N.M. Johnson. 1977. Biogeochemistry of a forested ecosystem. Springer-Verlag, New York Inc. 146 pp.

Likens, G.E., F.H. Bormann, R.S. Pierce, and W.A. Reiners. 1978. Recovery of a deforested ecosystem. Science 199:492-496.

Liljestrand, H.M. 1981. Personal communication. University of Texas, Austin, Texas.

Liljestrand, H.M., and J.J. Morgan. 1978. Chemical composition of acid precipitation in Pasadena, California. Environ. Sci. Technol. 12:1271-1273.

Liss, P.S. and P.G. Slater. 1974. Mechanism and rate of gas transfer across the air-sea interface. pp. 354-368 In Atmosphere-Surface Exchange of Particulate and Gaseous Pollutants. ERDA Symp. No. 38, Richland, Washington, 1974.

Liu, S.C. 1978. Possible nonurban environmental effects due to carbon monoxide and nitrogen oxide emissions. pp. 65-80. *In* Levine and Schryer (eds.) Man's Impact on the Troposphere. NASA *Ref.* Pub. 1022.

Lloyd, R., and D.H.M. Jordan. 1964. Some factors affecting the resistance of rainbow trout (*Salmo gairdneri*, Richardson) to acid waters. Int. J. Air Water Pollut. 8:393-403.

Loftus, K.H. 1976. Science for Canada's fisheries rehabilitation needs. J. Fish. Res. Board Can. 33:1822-1857.

Loucks, O.L. 1981. Water balance and flushing time as factors in midwest lake acidification. Paper presented at meeting of the American Geophysical Union, May 1981. The Institute of Ecology, Indianapolis.

Loucks, O.L., R.W. Usher, R.W. Miller, W. Swanson, and D. Rapport. 1981. Assessment of sensitivity measures for evaluating resources at risk from atmospheric pollutant deposition. Report submitted U.S. EPA Environmental Research Laboratory-Duluth. The Institute of Ecology (TIE), Indianapolis. 178 pp.

Makarewicz, J.C., and G.E. Likens. 1979. Structure and function of the zooplankton community of Mirror Lake, New Hampshire. Ecol. Monogr. 49:109-127.

Malley, D.F., D.L. Findlay, and P.S.S. Chang. 1981. Ecological effects of acid precipitation on zooplankton. In press.

McFee, W.W. 1980. Sensitivity of soil to acid precipitation. USEPA-600/3-80-013. USEPA Environmental Research Lab., Corvallis, Oregon. 186 pp.

McIntyre, J.W. 1979. Status of Common Loons in New York from a historical perspective. pp. 117-121. *In* S.A. Sutcliffe (ed.) The Common Loon. Proc. Second N.A. Conf. *on* Common Loon Research and Management. National Audubon Society, N.Y. 162 pp.

McLean, R.A.N. 1981. The relative contribution of sulfuric and nitric acid in acid rain to the acidification of the ecosystem: Implications for control strategy. J. Air Pollut. Contr. Ass. (in press).

Menendez, R. 1976. Chronic effects of reduced pH on brook trout (*Salvelinus fontinalis*). J. Fish. Res. Board Can. 33:118-123.

Möller, U., and G.J. Schumann. 1970. Mechanisms of transport from the atmosphere to the earth's surface. J. Geophys. Res. 75:3013-3019.

Mount, D.I. 1973. Chronic effect of low pH on fathead minnow survival, growth and reproduction. Water Res. 7:987-993.

Muniz, I.P., and H. Leivestad. 1980. Acidification-effects on freshwater fish. pp. 84-92. *In* D.Drabløs and A. Tollan (eds.) Ecological Impact of Acid Precipitation. Proceedings of an international conference, Sandefjord, Norway, March 11-14, 1980. SNSF Project, Norway, 1980.

NAQUADAT. 1973.

National Academy of Sciences (NAS). 1977. Nitrogen Oxides. Medical and Biological Effects of Environmental Pollutants. National Academy of Sciences, Washington, D.C. 333 pp.

National Academy of Sciences (NAS). 1978. An assessment of mercury in the environment. National Academy of Sciences, National Research Council, Washington, D.C. 185 pp.

Neville, C.M. 1979. Sublethal effects of environmental acidification on rainbow trout (*Salmo gairdneri*). J. Fish. Res. Board Can. 36:84-87.

Nicholls, K.H., J.L. Beaver, and R.H. Estabrook. 1981. Lakewide odours in Ontario and New Hampshire caused by *Chrysochromulina breviturrita* Nich. (Prymnesiophyceae). Ontario Ministry of the Environment Report No. APIOS 001/81. Toronto, Ontario, Canada. 11 pp.

Nicolson, J.A.. 1977. Summary Tech. Rep., Pluarg Task C Activity 2, Forested watershed studies, December 1, 1977, Environ. Canada, Great Lakes Forest Research Cent., Saulte Ste. Marie, Ontario, Canada.

Nielsen, C.L., F.H. Pough and J.A. Gorn. 1977. The effect of acid precipitation on reproduction in salamanders: Egg transplantation studies. Amer. Zool. 17(4):947 (abstract only).

Nilsson, S.C., and I.N. Nilsson. 1978. Breeding bird community and species richness on lakes. Oikos 31:214-221.

Nol[illegible], K.M. 1979. The effect of pH stress on developing Rana pipiens and the effect of calcium ions in relieving pH stress. Honours B.Sc. thesis, Univ. of Toronto, Toronto, Ontario, Canada. 9 pp.

Norton, S.A. 1976. Changes in chemical processes in soils caused by acid precipitation. USDA Forest Service Gen. Tech. Rep. NE-23, pp. 711-724.

Norton, S.A. 1980. Geologic factors controlling the sensitivity of aquatic ecosystems to acidic precipitation, pp. 521-531. In D.S. Shriner, C.R. Richmond and S.E. Lindberg (eds.) Atmospheric Sulfur Deposition: Environmental Impact and Health Effects. Ann Arbor Science, Ann Arbor, Michigan. 568 pp.

Nyholm, N.E.I., and H.E. Myhrberg. 1977. Severe eggshell defects and impaired reproductive capacity in small passerines in Swedish Lapland. Oikos 29:336-341.

Oak Ridge National Laboratory (ORNL). 1977. Environmental, Health and Control Aspects of Coal-Conversion: An Information Overview. H.M. Braunstein, E.D. Copenhaver and H.A. Pfuderer (eds.) ORNL/EIS-94. Volume I. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Oden, S., and T. Ahl. 1970. The acidification of Scandinavian waters. Ymer. Arsbok. 103-122.

Oglesby, R.T. 1977a. Phytoplankton summer standing crop and annual productivity as functions of phosphorus loading and various physical factors. J. Fish. Res. Board Can. 34:2255-2270.

Oglesby, R.T. 1977b. Relationships of fish yield to lake phytoplankton standing crop, production, and morphoedaphic factors. J. Fish. Res. Board Can. 34:2271-2279.

Okland, J. 1969. Om forsuring av vassdrag og betydningen av surhetsgraden (pH) for fiskens naeringsdyr: Ferskvann. Fauna 22:140-147.

Okland, K.A. 1980. Ecology and distribution of Acellus aquaticus (L) in Norway, including relation to acidification in lakes. SNSF Project, Norway, IR52/80, 70 pp.

Olson, R.J., D.W. Johnson, and D.S. Shriner. 1981. Regional assessment of potential sensitivity of soils in the eastern United States to acid precipitation. Draft manuscript. Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Olver, C. 1981. Personal communication. Ontario Minist. of the Environ. Toronto, Ontario, Canada.

Ontario Ministry of Environment. 1981. Acid sensitivity survey of lakes in Ontario. March 1981. Report APl-002/81. Acid Precipitation in Ontario Study (APIOS) Coordinator, Mr. E. Piche, 40 St. Clair Ave. W., 6th Floor, Toronto, Ontario, Canada M4V 1M2.

Orser, P.N., and D.K. Shure. 1972. Effects of urbanization on the salamander, Desmognathus fuscus fuscus. Ecology 53:1148-1154.

Overrein, L.N., H.M. Seip, and A. Tollan. 1980. Acid precipitation-effects on forest and fish: Final report of the SNSF-project 1972-1980. Res. Report 1980, P.O.Box 333, Blindern, Oslo, Norway, 175 pp.

Packer, R.K., and W.A. Dunson. 1972. Anoxia and sodium loss associated with the death of brook trout at low pH. Comp. Biochem. Physiol. 41A, 17-26.

Pederson, G.L., E.B. Welch, and A.H. Litt. 1976. Plankton secondary productivity and biomass: Their relation to lake trophic state. Hydrobiologia 50:129-144.

Peterson, R.H. Personal communication. Canada Dept. of Fisheries and Oceans, St. Andrews, New Brunswick, Canada.

Peterson, R.H. 1980. Water chemistry of ten lakes in southern New Brunswick. Canadian Tech. Rep. Fish. Aquatic Sci. No. 962.

Peverly, J.H. 1981. Personal communication. Department of Agronomy, Cornell University, Ithaca, New York.

Pfeiffer, M.H., and P.J. Festa. 1980. Acidity status of lakes in the Adirondack region of New York in relation to fish resources. Progress Report. New York State Dept. of Environmental Conservation. Albany, New York.

Poldoski, J.E., and G.E. Glass. 1975. Considerations of trace element chemistry for streams in the Minnesota-Ontario border area. pp. 901-922. In T.C. Hutchinson (ed.) International Conference on Heavy Metals in the Environment, Toronto, Ontario, Canada, October 27-31, 1975. National Research Council of Canada, Ottawa, Ontario, Canada.

Pough, F.H. 1976. Acid precipitation and embryonic mortality of spotted salamanders, Ambystoma maculatum. Science 192:68-70.

Pough, F.H., and R.E. Wilson. 1977. Acid precipitation and reproductive success of Ambystoma salamanders. Water Air Soil Pollut. 7:307-316.

Raglund, K.W., and K.E. Wilkening. 1981. Relationship between mesoscale acid precipitation and meteorological factors. In F.M. D'Itri (ed.) The Effects of Acid Precipitation on Ecological Systems in the Great Lakes Region. Proceedings of a conference, April 1-3, 1981. Ann Arbor Science Publishers, Ann Arbor, Michigan. (In press.)

Raddum, G.G. 1980. Comparison of benthic invertebrates in lakes with different acidity. pp. 330-331. In D.Drabløs and A. Tollan (eds.) Ecological Impact of Acid Precipitation. Proceedings of an international conference, Sandefjord, Norway, March 11-14, 1980. SNSF Project, Norway, 1980.

Raddum, G.G., A. Hobaek, E.R. Lomsland and T. Johnson. 1980. Phytoplankton and zooplankton in acidified lakes in South Norway. pp. 332-333. In D.Drabløs and A. Tollan (eds.) Ecological Impact of Acid Precipitation. Proceedings of an international conference, Sandefjord, Norway, March 11-14, 1980. SNSF Project, Norway, 1980.

Ramberg, L. 1981. Increase in stream pH after forest drainage. Ambio 10:34.

Rasmussen, K.H., M. Taheri, and R.L. Kabel. 1975. Global emissions and natural processes for removal of gaseous pollutants. Water Air Soil Pollut. 4:33-64.

Raven, J.A. 1970. Exogenous inorganic carbon sources in plant photosynthesis. Biol. Rev. 45:167-221.

Reckhow, K.H. 1979. Empirical lake models for phosphorus: Development, applications, limitations, and uncertainty. In D. Scavia and A. Robertson (eds.) Perspectives on Lake Ecosystem Modeling. Ann Arbor Sci., Ann Arbor, Michigan.

Reuss, J.O. 1976. Chemical and biological relationships relevant to the effect of acid rainfall on the soil-plant system. In Proc. 1st Int. Symp. on Acid Precipitation and the Forest Ecosystem. U.S.D.A. Forest Service Gen. Tech. Rep. NE-23. 1074 pp.

Ricker, W.E. 1972. Hereditary and environmental factors affecting certain salmonid populations. p. 19-160. In The Stock Concept in Pacific Salmon. H.R. MacMillan Lectures in Fisheries. Univ. British Columbia, Vancouver, B.C., Canada.

Robinson, E., and R.C. Robbins. 1970. Gaseous nitrogen compound pollutants from urban and natural sources. J. Air Pollut. Control Assoc. 70(5):305-306.

Robinson, G.D., W.A. Dunson, J.E. Wright, and G.E. Mamolito. 1976. Differences in low pH tolerance among strains of brook trout (Salvenlinus fontinalis). J. Fish. Biol. 8:5-17.

Rodhe, H. 1978. Budgets and turn-over times of atmospheric sulfur compounds. Atmos. Environ. 12(1-3):671-680.

Roff, J.C., and R.E. Kwiatkowski. 1977. Zooplankton and zoobenthos communities of selected northern Ontario lakes of different acidities. Can. J. Zool. 55:899-911.

Rosenquist, I., P. Jorgensen and H. Rueslatten. 1980. The importance of natural H^+ production for acidity in soil and water. pp. 240-241. In D.Drabløs and A. Tollan (eds.) Ecological Impact of Acid Precipitation. Proceedings of an international conference, Sandefjord, Norway, March 11-14, 1980. SNSF Project, Norway, 1980.

Rosseland, B.O., I. Sevaldrud, D. Svalastog, and I.P. Muniz. 1980. Studies on fresh water fish populations - effects of acidification on reproduction population structure, growth, and food selection. pp. 336-337. In D.Drabløs and A. Tollan (eds.) Ecological Impact of Acid Precipitation. Proceedings of an international conference, Sandefjord, Norway, March 11-14, 1980. SNSF Project, Norway, 1980.

Ruby, S.M., J. Aezel, and E.R. Craig. 1977. The effects of depressed pH on oogenesis in flagfish Jordanella floridae. Water Res. 11:757-762.

Ruby, S.M., J. Aezel, and G.R. Craig. 1978. The effects of depressed pH on spermatogenesis in flagfish Jordanella floridae. Water Res. 12:621-626.

Ryan, P.M., and H.H. Harvey. 1980. Growth responses of yellow perch, Perca flavescens (Mitchill), to lake acidification in the La Cloche Mountain lakes of Ontario. Environ. Biol. Fish. 5:97-108.

Ryman, N., and G. Stahl. 1981. Genetic perspectives of identification and preservation of Scandinavian stocks of fish. Can. J. Fisheries Aquat. Sci. (in press).

Scheider, W.A. 1981. Personal communication. Ontario Ministry of the Environ., Toronto, Ontario, Canada.

Scheider, W.A., B. Cave, and J. Jones. 1976. Reclamation of acidified lakes near Sudbury, Ontario by neutralization and fertilization. Ontario Ministry of Environment report. 48 pp. plus figures.

Scheider, W.A., D.S. Jeffries, and P.J. Dillon. 1978. Effects of acidic precipitation on Precambrian freshwaters in southern Ontario. Ontario Ministry of Environ., Toronto, Ontario, Canada. 25 pp.

Scheider, W.A., W.R. Snyder, and B. Clark. 1979a. Deposition of nutrients and ions by precipitation in south-central Ontario. Water Air Soil Pollut. 12:171-185.

Scheider, W.A., D.S. Jeffries, and P.J. Dillon. 1979b. Effects of acidic precipitation on Precambrian freshwaters in southern Ontario. J. Great Lakes Res. 5:45-51.

Scheider, W.A., D.S. Jeffries, and P.J. Dillon. 1980. Bulk deposition in the Sudbury and Muskoka-Haliburton areas of Ontario during the shutdown of INCO Ltd. in Sudbury. Ont. Minist. of the Environ., Rexdale, Ontario, Canada. May 1980. 25 pp.

Scheider, W.A., D.S. Jeffries, and P.J. Dillon. 1981. Bulk deposition in the Sudbury and Muskoka-Haliburton areas of Ontario during the shutdown of Inco Ltd. in Sudbury. Atmos. Environ. 15:(in press).

Schindler, D.W. 1980. Experimental acidification of a whole lake - a test of the oligotrophication hypothesis. pp. 370-374. *In* D.Drabløs and A. Tollan (eds.) Ecological Impact of Acid Precipitation. Proceedings of an international conference, Sandefjord, Norway, March 11-14, 1980. SNSF Project, Norway, 1980.

Schindler, D.W. 1981. Personal communication. Canada Dept. of Fish and Oceans, Freshw. Inst., Winnepeg, Manitoba, Canada.

Schindler, D.W., R.H. Hesslein, R. Wagemann, and W.S. Broecker. 1980. Effects of acidification of mobilization of heavy metals and radionuclides from the sediments of a freshwater lakes. Can. J. Fisheries Aquat. Sci. 37:373-377.

Schindler, D.W., and S.K. Holmgren. 1971. Primary production and phytoplankton in the Experimental Lakes Area, northwestern Ontario and other low carbonate waters, and a liquid scintillation method for determining 14C activity in photosynthesis. J. Fish. Res. Board Can. 28:189-201.

Schindler, D.W., R.W. Newbury, K.G. Beaty, and P. Campbell. 1976. Natural water and chemical budgets for a small Precambrian lake basin in central Canada. J. Fish. Res. Board Can. 33:2526-2543.

Schindler, D.W., and J.E. Nighswander. 1970. Nutrient supply and primary production in Clear Lake, eastern Ontario. J. Fish. Res. Board Can. 27:2009-2036.

Schofield, C.L. 1976. Acid precipitation: Effects on fish. Ambio 5:228-230.

Schofield, C.L. 1980. Processes limiting fish populations in acidified lakes. pp. 345-356. *In* D.S. Shriner, C.R. Richmond, and S.E. Lindberg (eds.) Atmospheric Sulfur Deposition: Environmental Impact and Health Effects. Ann Arbor Sci., Ann Arbor, Michigan.

Schofield, C.L. 1981. Personal communication. Cornell University, Ithaca, New York.

Schofield, C.L., and J.R. Trojnar. 1980. Aluminum toxicity to brook trout (*Salvelinus fontinalis*) in acidified waters. pp. 341-366. *In* T.Y. Toribara, M.W. Miller and P.E. Morrow (eds.) Polluted Rain. Plenum Press, New York.

Scrivener, J.C. 1975. Water, water chemistry and hydrochemical balance of dissolved ions in Carnation Creek watershed, Vancouver Island, July 1971 -May 1974. Environment Canada Fish. Mar. Serv. Tech. Rep. No. 564.

Sehmel, G.A., and W.H. Hodgson. 1974. Predicted dry deposition velocities. pp. 399-419. *In* Atmosphere-Surface Exchange of Particulate and Gaseous Pollutants. ERDA Symposium Series 38.

Sehmel, G.A., and S.L.J. Sutter. 1974. Particle deposition rates on a water surface as a function of particle diameter and air velocity. J. Rech. Atm. 3:911-916.

Seip, H.M. 1980. Acidification of freshwater-sources and mechanisms. pp. 358-359. *In* D.Drabløs and A. Tollan (eds.) Ecological Impact of Acid Precipitation. Proceedings of an international conference, Sandefjord, Norway, March 11-14, 1980. SNSF Project, Norway, 1980.

Seip, H.M., G. Abrahamsen, N. Christophersen, E.T. Gjessing, and A.O. Stuanes. 1980. Snow and meltwater chemistry in mini-catchments. SNSF Project, IR 53/80, 1432 Aas-NLH, Norway, 51 p.

Sievering, H. 1979. Dry deposition of atmospheric aerosols to Lake Michigan as a function of meteorology and aerosol size. pp. 518-521. *In* Proc. Amer. Met. Soc. Symp. on Atmos. Diff. and Air Pollut. Reno, Nevada, January 15-18, 1979. Am. Met. Soc. Publ.

Slinn, W.G.N. 1979. Modeling of atmospheric particulate deposition to lakes. Presented at the ACS Symposium on "Atmospheric Input of Pollutants to Natural Waters," Sept. 9-14, 1980. Washington, D.C.

Slinn, W.G.N. 1980. Precipitation scavenging. *In* Meteorology and Power Production, U.S. Dept. of Energy.

Slinn, W.G.N., L. Hasse, B.B. Hicks, A.W. Hogan, D.Lal, P.S. Liss, K.O. Munich, G.A. Sehmel, and O. Vittori. 1978. Some aspects of the transfer of atmospheric trace constituents past the air/sea interface. Atmos. Environ. 12:2055-2087.

Slinn, G., and S.A. Slinn. 1981. Modeling of atmospheric particulate deposition to natural waters. *In* S. Eisenreich (ed.) Atmospheric Input of Pollutants to Natural Waters. Ann Arbor Science, in press.

Smith, M.W. 1938a. A preliminary account of the fish populations in certain Nova Scotian lakes. Trans. Amer. Fish. Soc. for 1937. 67: 178-183.

Smith, M.W. 1938b. A survey of Lake Jesse, Nova Scotia. Proc. Nova Scotian Inst. Sci. 19(1):11-16.

Smith, M.W. 1948. Improved trout angling in a small lake after poisoning undesirable fish. Can. Fish. Culturist 3(4):3-6.

Smith, M.W. 1952. Limnology and trout angling in Charlotte County lakes, New Brunswick. J. Fish. Res. Board Can. 8:383-452.

Smith, M.W. 1961. A limnological reconnaissance of a Nova Scotian brownwater lake. J. Fish. Res. Board Can. 18(3):463-478.

Smith, R.W., and D.G. Frey. 1971. Acid mine pollution effects on lake biology. Water Pollut. Cont. Res. 18050 EEC, EPA, Washington, D.C.

Snekvik, E. 1974. Unpublished report. (Cited in E.T. Gjessing *et al.* 1974. Impact of acid precipitation on forest and freshwater ecosystems of Norway. SNSF Project. FR 6/76.)

Söderlund, R., and B.H. Svensson. 1976. The global nitrogen cycle. pp. 23-74. *In* Svensson and Söderlund (eds.) Nitrogen, Phosphorous, and Sulphur - Global Cycles. Scope Report 7. Ecol. Bull. (Stockholm) 22.

Sprules, W.G. 1975a. Factors affecting the structure of limnetic crustacean zooplankton communities in central Ontario lakes. Verh. Int. Verein. Limnol. 19:635-643.

Sprules, W.G. 1975b. Midsummer crustacean zooplankton communities in acid-stressed lakes. J. Fish. Res. Board Can. 32:389-395.

Spry, D.J., C.M. Wood, and P.V. Hodson. 1981. The effects of environmental acid on freshwater fish with particular reference to the softwater lakes in Ontario and the modifying effects of heavy metals. A literature review. Can. Tech. Rep. Fish. Aquat. Sci. No. 999. 145 pp.

Steeman-Nielsen, N.E. 1944. Dependence of freshwater plants on quality of carbon dioxide and hydrogen ion concentration. Dansk. Bot. Ark. 11:8,1.

Steeman-Nielsen, N.E. 1946. Carbon sources in the photosynthesis of aquatic plants. Nature, Lond. 158-594.

Stewart, R.W., S. Hameed, and J. Pinto. 1978. The natural and perturbed troposphere. pp. 27-64. *In* Levine and Schryer (eds.) Man's Impact on the Troposphere. NASA Ref. Pub. 1022.

Stokes, P.M. 1981. Personal communication. Botany Dept., Univ. of Toronto, Toronto, Ontario, Canada.

Strijbosch, H. 1979. Habitat selection of amphibians during their aquatic phase. Oikos 33:363-372.

Suns, K. 1981. Personal communication. Ontario Ministry of the Environment, Toronto, Ontario, Canada.

Suns, K., C. Curry, and D. Russell. 1980. The effects of water quality and morphometric parameters on mercury uptake by yearling yellow perch. OME Tech. Rep. LTS 80-1. 16 pp.

Svärdson, G. 1974. Review of the Laboratory's Activity and the Projects of the Year 1974. Inform. Institute of Freshwater Research, Drottningholm 1, Sweden.

Swartz, F.A., W.A. Dunson, and J.E. Wright, Jr. 1978. Genetic and environmental factors involved in increased resistance of brook trout to sulfuric acid solutions and mine acid polluted waters. Inst. Res. Land Water Resour., Penn. St. Univ., September 1978, 84 pp.

Sze, N.D. 1977. Anthropogenic CO emissions: Implications for the atmospheric $CO-OH-CH_4$ cycle. Science 195:673-675.

Thomas, J.F.J. 1960. Water Survey Rep. No. 11. Queens Printer, Ottawa, Ontario, Canada, 158 pp.

Thompson, F.C., and H.A. Wilson. 1975. Tolerance and synthetic activity of sewage microorganisms in acid mine water. West Virginia University Bulletin. Series 76, No. 5-1, 60 pp.

Thompson, M.E. 1981. The cation denudation rate as a quantitative index of sensitivity of eastern Canadian rivers to acidic atmospheric precipitation. Water Air Soil Pollut., in press.

Thompson, M.E. 1981. Personal communication. Environment Canada National Water Research Inst. Burlington, Ontario, Canada.

Thompson, M.E., F.C. Elder, A.R. Davis, and S. Whitlow. 1980. Evidence of acidification of rivers of Eastern Canada. pp. 244-245. *In* D. Drabløs and A. Tollan (eds.) Ecological Impact of Acid Precipitation. Proceedings of an international conference, Sandefjord, Norway, March 11-14, 1980. SNSF-Project, Norway, 1980.

TIE. 1981. Regional Assessment of Aquatic Resources at Risk from Acidic Deposition. Interim Report to the U.S. Congress, Office of Technology Assessment. The Institute of Ecology. Indianapolis, Indiana.

Traaen, T.S. 1980. Effects of acidity on decomposition of organic matter in aquatic environments. pp. 340-341. *In* D.Drabløs and A. Tollan (eds.) Ecological Impact of Acid Precipitation. Proceedings of an international conference, Sandefjord, Norway, March 11-14, 1980. SNSF Project, Norway, 1980.

Trivelpiece, W., S. Brown, A. Hicks, R. Fekete, and N.J. Volkman. 1979. An analysis of the distribution and reproductive success of the common loon in the Adirondack Park, New York. pp. 45-55. *In* S.A. Sutcliffe (ed.) The Common Loon. Proc. Second. N.A. Conf. on Common Loon Research and Management. National Audubon Society, New York. 162 pp.

Trojnar, J.R. 1977. Egg and larval survival of white suckers (*Catostomus commersoni*) at low pH. J. Fish. Res. Board Can. 34:262-266.

Tuttle, J.H., C.I. Randalls, and P.R. Dugan. 1968. Activity of microorganisms in acid mine water. I. Influence of acid water on aerobic hetertrophs of a normal stream. J. Bacteriol. 95:1495-1503.

Tuttle, J.H., P.R. Dugan, C.B. MacMillan, and C.I. Randalls. 1969. Microbial dissimilatory sulfur cycle in acid mine water. J. Bacteriol. 97:594-602.

Ulrich, B., R. Mayer, and P.K. Khanna. 1980. Chemical changes due to acid precipitation in a loess-derived soil in central Europe. Soil Science 130:193-199.

U.S. Fish and Wildlife Service. 1981. Results of modeling workshops concerning acid precipitation effects on aquatic biota. U.S. FWS Office of Biological Services. Manuscript in review.

Vollenweider, R.A. 1975. Input-output models with special reference to the phosphorus loading concept in limnology. Schweiz. Z. Hydrologie 37:53-84.

Wang, C., and D.R. Coote. 1980. Sensitivity classification of agricultural land to long term acid precipitation in eastern Canada. Unpublished manuscript and map. 16 pp.

Water Quality Branch, 1981. Environment Canada, Moncton, New Brunswick, Canada.

Watt, W.D. 1980. Unpublished data from the Dept. Fish and Oceans, Halifax, N.S., Canada.

Watt, W.D. 1981. Present and potential effects of acid precipitation on the Atlantic salmon in eastern Canada. In Proceedings of the Conf. on Acid Rain and the Atlantic Salmon, Portland, Maine, Nov. 22-23, 1980. Special Publication Series No. 10, March 1981. ASF, New York.

Watt, W.D. 1981. Dept. of Fish and Oceans, Freshwater Div., Halifax, N.S., Canada. Unpublished manuscript.

Watt, W.D., D. Scott, and S. Ray. 1979. Acidification and other chemical changes in Halifax County lakes after 21 years. Limnol. Oceanogr. 24:1154-1161.

Whelpdale, D.M. 1979. Acidic deposition. In Proceedings of EPRI/CERL Workshop on Ecological Effects of Acidic Precipitation. Galloway, Scotland, September 1979. EPRI/SOA 77-403. Electric Power Research Inst., Palo Alto, California. 42 pp.

Wiederholm, T., and L. Eriksson. 1977. Benthos of an acid lake. Oikos 29:261-267.

Wilson, D.E. 1979. The influence of humic compounds in sometric determination of total inorganic carbon in freshwater. Arch. Hydrobiol. 87:379.

Wiltshire, J.F., and J.R. Machell. 1981. A study of acidification in sixteen lakes in mainland Nova Scotia and southern New Brunswick. A preliminary report. Environmental Protection Service, Atlantic Region, Halifax, Nova Scotia, Canada.

Wium-Andersen, S., and J.M. Andersen. 1972. CO_2 content of the interstitial water in the sediment of Grane Langso, a Danish Lobelia lake. Limnol. Oceanogr. 17:943-947.

Work Group 2. 1981. Memorandum of Intent. U.S./Canada Agreement for Transboundary Pollutants. U.S. Dept. of State.

Wright, R.F., and E. Snekvik. 1978. Acid precipitation: Chemistry and fish populations in 700 lakes in southernmost Norway. Verh. Int. Verein. Limnol. 20:765-775.

Wright, R.F., and E.T. Gjessing. 1976. Acid Precipitation: Changes in the chemical composition of lakes. Ambio 5:219-223.

Wright, R.F., R. Harriman, A. Henriksen, B. Morrison and L.A. Caines. 1980. Acid lakes and streams in the Galloway area, southwestern Scotland. pp. 248-249. In D. Drabløs and A. Tollan (eds.) Ecological Impact of Acid Precipitation. Proceedings of an international conference, Sandefjord, Norway, March 11-14, 1980. SNSF Project, Norway, 1980.

Yan, N.D. 1979. Phytoplankton of an acidified, heavy metal-contaminated lake near Sudbury, Ontario; 1973-1977. Water Air Soil Pollut. 11: 43-55.

Yan, N.D., and G.E. Miller. 1981. Characterization of Study Lakes. In Studies of Lakes and Watersheds near Sudbury, Ontario. Ontario Ministry of Environment, Tech. Rep., Toronto, Ontario, Canada

Yan, N.D., and P.M. Stokes. 1976. The effects of pH on lake water chemistry and phytoplankton in a La Cloche Mountain lake. pp. 127-137. In Proc. 11th Can. Symp. Water Pollution Research in Canada.

Yan, N.D., and P.M. Stokes. 1978. Phytoplankton of an acidic lake and its responses to experimental alterations of pH. Environ. Conserv. 5(2):93-100.

Yan, N.D., and R. Strus. 1979. Crustacean zooplankton communities of acidic, metal-contaminated lakes near Sudbury, Ontario. Ont. Ministry Environment. Tech. Rep. LTS 79-4. Toronto, Ontario, Canada. 27 pp.

Yan, N.D., and R. Strus. 1981. Crustacean zooplankton communities of acidic, metal-contaminated lakes near Sudbury, Ontario. Can. J. Fisheries Aquat. Sci. 37:2282-2293.

Zeman, L.J. 1975. Hydrochemical balance of a British Columbia mountainous watershed. Catena 2:81-94.

Zimmerman, A.P., and H.H. Harvey. 1979. Sensitivity to acidification of waters of Ontario and neighbouring states. Final report to Ontario Hydro, University of Toronto, Toronto, Ontario, Canada. 118 pp.

APPENDIX C

State of Wisconsin \ DEPARTMENT OF NATURAL RESOURCES

Anthony S. Earl
Secretary

BOX 7921
MADISON, WISCONSIN 53707

IN REPLY REFER TO: 3200

Mr. Douglas Costle
U.S. Environmental Protection Agency
Washington, D.C. 20460

Dear Mr. Costle:

The State of Wisconsin has a keen interest and a genuine concern for the growing problem of acid precipitation in our country.

Research performed in Scandinavia, Canada and New York links acid rain to the disappearance of sport fish from lakes that once supported a diversity of aquatic life. In vulnerable areas acid rain also threatens to impair soil fertility, forest and agricultural production and tourism if the sources of its air pollution precursors are not identified and controlled.

Northern Wisconsin, northern Minnesota and upper Michigan possess environmental features identical to regions already damaged by acid rain. These areas are prized by residents and visitors for their scenery, fish and wildlife and varied recreational opportunities. They are commercially important for timber, tourism and some agriculture.

Preliminary research conducted on Wisconsin and Minnesota lakes underscores their susceptibility to acid precipitation. In addition, rain collected and analyzed in Wisconsin in 1979 was found to be ten times more acid than normal--the same level recorded in New York's Adirondack Mountains where many high altitude lakes now are devoid of fish.

In the last few months we have taken various steps to evaluate the problem, and establish a plan that will eventually lessen the threat to our state. A summary of our various acid rain activities is as follows:

1. On February 14, 1980 I formed an internal, multi-disciplinary Acid Deposition Task Force to define the status and finding of acid rain research in Wisconsin. The task force's report, due this summer, will list the research areas needed to fill gaps in the state's current information, and will outline coordination efforts Wisconsin should undertake with neighboring states to expand its research base.

2. On March 27 the Wisconsin Natural Resources Board adopted a resolution (attached) which cites environmental concerns held by this Department regarding acid rain. It asks for more funding assistance from the federal government, and stresses the need for a regional approach to acid rain studies that avoids overlap and maximizes interstate cooperation.

3. On April 23, 1980, I sought and received the endorsement of the Natural Resources Board to pursue various policies which will eventually minimize emissions that are the precursors of acid rain. Attached is a copy of the approved request I took to the Natural Resources Board, which lists six specific items that require your immediate attention.

I request that you critically evaluate these six items as to their potential for dealing with the acid rain problem. Please advise me as soon as possible regarding your Agency's intended action on these six items.

I am sending a copy of this letter to other states most severely impacted by acid deposition in order to inform them of our position on the subject. We hope that your Agency will take immediate steps to remedy the acid rain problem either by exercising your existing authority under the Clean Air Act, or by seeking changes in the Act that would give you this authority.

Your swift action on this matter is essential to the protection of our vulnerable resources.

Sincerely,

Anthony S. Earl

Anthony S. Earl
Secretary

Attach.
cc: Administrator - EPA, Region V
Governors and Legislative Representatives
Impacted States in Regions I Through V

Natural Resources Board Resolution on Acid Rain

Scheduled For Adoption on March 27, 1980

WHEREAS, many lakes in Scandinavia, Ontario and New York's Adirondack Mountains no longer support fish and other aquatic life due to acid precipitation; and

WHEREAS, many lakes in northern Wisconsin, northern Minnesota and Upper Michigan possess features similar to lakes damaged elsewhere; and

WHEREAS, Wisconsin and Minnesota have been identified as being the most susceptible states in the nation for additional acid rain damage; and

WHEREAS, acid precipitation may potentially damage fish and other aquatic life in northern Wisconsin enough to affect tourism; and

WHEREAS, acid precipitation may affect productivity of Wisconsin's soils, forests and agriculture; and

WHEREAS, information on interstate transport of air pollution into Wisconsin, and potential declines in aquatic life, soil fertility, and agricultural and forest production is extremely limited; and

WHEREAS, current national energy policy relies heavily on expanded use of coal; and

WHEREAS, EPA is currently allocating insufficient funds for acid rain research in Wisconsin, Minnesota, and Michigan;

NOW, THEREFORE, BE IT RESOLVED, that the Wisconsin Natural Resources Board does hereby strongly urge appropriate officials in the Federal Congress and executive branch to allocate adequate research funds to investigate the sources and potential impact of acid rain on vulnerable portions of the states of Wisconsin, Minnesota and Michigan;

BE IT FURTHER RESOLVED, that the Board urges the Environmental Protection Agency to investigate appropriate steps to control air pollution from sources contributing to the acid rain potential in the states of Wisconsin, Minnesota and Michigan.

SECRETARY'S MATTER
for
NATURAL RESOURCES BOARD MEETING
April 23, 1980

ACID RAIN

The Wisconsin Department of Natural Resources was a participant in the EPA-sponsored Acid Rain Conference at Springfield, Virginia on April 8 and 9, 1980.

That conference has concluded acid deposition is a real and growing phenomenon with substantial real and potential effects on biota, soils and recreational waters.

I am hereby seeking the endorsement of this Board to pursue the following policies in order to minimize the cultural emissions that are the precursors of acid rain:

1. The Department seek administrative and regulatory action under Section 111(d) of the Clean Air Act. (Section 111(d) authorizes the establishment of standards of performance for any existing source for any air pollutant and procedures for implementation and enforcement of such standards of performance.)
2. A nationwide requirement for coal washing in order to remove substantial quantities of pyritic compounds.
3. Legislative action to amend the Clean Air Act to require nationwide emission limits.
4. Retrofitting of existing power plants to meet nationwide emission limits.
5. Nationwide emission monitoring.
6. Nationwide consistency among EPA regions in requirements and enforcement.

STATEMENT OF ROBERT A. ARNOTT, ASSISTANT DIRECTOR, COLORADO DEPARTMENT OF HEALTH, DENVER, COLO.

My name is Robert A. Arnott and I am an Assistant Director of the Colorado Department of Health with responsibility for environmental and health protection programs. I have a Ph.D. in physical chemistry from the University of Wisconsin and prior to my present position I held program management positions in both the Wisconsin and Illinois air programs as well as a faculty position in the University of Wisconsin system.

Acid rain has principally been considered a problem of the Eastern United States and most research efforts have been concentrated in this area. However, there is increasing evidence and concern that acid deposition is a national phenomena with the potential to significantly impact the Western United States, particularly at higher elevations.

This concern is particularly important in Colorado as we are currently faced with major industrial growth in some of the remote areas of the State. Oil shale processing, synthetic fuel production and other energy related projects are inevitable sources of air pollution which could cause increased acid deposition in Colorado. Additionally, the accompanying population increases will increase the emissions from mobile sources throughout the State.

Currently, acid deposition is monitored in Colorado at a limited number of sites through the National Acid Deposition Program (NADP) and other research projects. Existing limited data supports the conclusion that the annual average pH of precipitation at the NADP sites in Colorado is approximately five, a pH significantly lower than the level accepted as normal for precipitation.

Dr. J. H. Gibson of the NADP program indicates that some areas of Colorado do have natural soils with a high neutralizing capacity. However, other areas, particularly at higher elevations where the major precipitation events occur, do not These areas are thus much more sensitive to acid deposition and will not accept significant future decreases in soil and lake buffering capacity without experiencing potentially irreversible damange. Research to date performed by Dr. Barry Hubert of Colorado College, Colorado Springs, Colorado has established an average Snow pH level of 4.7 at a site located on the Continental Divide. Individual storm events have produced pH levels as low as 4 to 4.5. Dr. Hubert attributes a great deal of the acidity to nitric acid which is highly associated with anthropogenic emissions of oxides of nitrogen in the Front Range area of Colorado.

Because of the concern for damage to our ecosystem by acid deposition, a special task force was established by the Governor's Science and Technology Advisory Council to study this potential problem in Colorado. The interim findings of this group support the conclusions reached by other researchers and governmental agencies. These findings indicate that while most of the agricultural soils and Great Plains and Plateau waters in the State have a large reserve of alkalinity, the high altitude lakes and streams and mountain terrestrial systems may be highly susceptible to acidification. This conclusion takes on added significance because the areas containing the most susceptible waters and soils (the alpine and sub-alpine mountainous areas) receive relative greater amounts of precipitation. One estimate indicates that as much as 25% of the total precipitation in Colorado falls on approximately 2% of the land area - the same general area which is considered most sensitive to acid deposition. This task force further recommended that Colorado participate in the organization and development of appropriate research programs into the nature of this problem.

All existing data indicates that Colorado does experience the acid rain phenomenon. Average pH levels are well below the expected "clean precipitation" concentrations.

It is equally evident that considerable scientific investigation remains to be accomplished. The extent of interstate transport, impacts of acid deposition on federal Class I areas, visibility impairment, materials damage, welfare effect and the relative roles of mobile and stationary sources all must be much more extensively investigated at the same time that major additional research is required to document the magnitude and pervasiveness of the impacts in Colorado and throughout the United States.

The State of Colorado strongly supports Congressional action to deal with the acid depositon problem and recommends, as a minimum, that the following elements be contained in any such action:

I. The level of research must be significantly expanded to include additional measurement of actual impacts, interstate and international transport from sources, relationships between acid deposition and visibility, increased knowledge of materials damage and welfare impacts and a determination of the chemistry and role of specific precursors, principally oxides of sulfur and oxides of nitrogen.

II. Reasonably and practicable measures should be immediately implemented to reduce emissions of oxides of sulfur and nitrogen from existing stationary sources and to define regional or state specific emission goals. These targets must be implemented over an interim time period, such as ten years and should consider both potential new emission sources as well as existing sources. This recommendation is in concert with the policy position on long range transport adopted by the State and Territorial Air Pollution Program Administrators in their June, 1981 recommendations on Clean Air Act reauthorization.

III. Specific statutory language should be enacted to allow broader authority to control long range and regional air pollution sources and impacts. This would include at least modifications to Sections 110(a) and 126 of the present Federal Clean Air Act.

IV. No relaxation of the mobile source oxides of nitrogen limitation should be enacted due to evidence which indicates that nitric acid deposition is a significant contributor to overall acid deposition, particularly in the Western United States.

It would not be good public policy to enact such a relaxation when the technology exists to meet the presently required standard and where increasing evidence points to the contribution of mobile source emissions to this serious problem.

In summary, Colorado has the potential to be seriously impacted by acid deposition and all reasonable mitigative measures should be implemented while the additional scientific information necessary to adequately define this significant environmental problem is obtained.

Statement of
William C. Gerstner
Executive Vice President
Illinois Power Company

October 29, 1981

Before
the
Senate Committee
on
Environment and Public Works

Committee Members, Ladies and Gentlemen:

My name is William C. Gerstner. I am Executive Vice President of Illinois Power Company and Chairman of the Utility Air Regulatory Group.[1/] I am speaking today on behalf of the Edison Electric Institute - the trade association of the electric utility industry. EEI's member companies generate most of the electricity used in the United States.

I would like to thank the members of the Committee for giving me the opportunity to testify today on S.1706, S.1709 and S.1718. The first two of these bills - S.1706 and S.1709 - would amend the Clean Air Act to establish stringent SO_2 emission reduction requirements for major stationary sources in

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[1/] UARG is an ad hoc group of 85 electric utilities, the Edison Electric Institute and the National Rural Electric Cooperative Association.

the 31 states bordering on and east of the Mississippi. The third bill - S.1718 - would amend the Clean Air Act to broaden significantly the scope of the provisions of the Act concerning interstate transport of air pollutants.

I. INTRODUCTION

Before turning to the specifics of the bills, I'd like to make it clear that we believe the emission reduction programs contained in S.1706 and S.1709 are unwarranted and that we oppose these bills. We believe that both bills, in departing dramatically from the approach Congress endorsed last year in enacting the Acid Precipitation Act of 1980,[2] ignore the pervasive scientific uncertainty that surrounds the acid deposition phenomenon. That Act established a comprehensive research program to investigate the causes and affects of acid deposition, and reflected Congress' judgment that acid rain related regulatory programs should not be undertaken until the extensive investigation of the phenomenon authorized by the Act (and now underway) has been conducted.[3] In sponsoring the legislation that led to the passage of the Acid Precipitation Act, Senator Moynihan himself underscored Congress' concern that premature action could prove disastrous:

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[2] 42 U.S.C.A. 8901 et seq. (1980 pamphlet).

[3] Id. at § 8904(b).

> [T]he Senate is proposing to learn something about the subject before it mandates solutions. It will be possible to make profoundly gross mistakes here if we do not do some research first, mistakes that would cost billions. [4]

We believe that there has been no new evidence since this statement was made which justifies rejecting the reasoned approach established by Congress last year.

The most disturbing aspect of S.1706 and S.1709 is their failure to address a host of critically important scientific and policy questions that must be resolved before intelligent conclusions can be drawn concerning the need for any acid rain regulatory program. The following discussion briefly notes several of the more pressing of these questions and indicates why we believe that the emissions reductions schemes contained in S.1706 and S.1709 are totally unjustified.

1. Are significant, adverse effects occurring as a result of ecosystem acidification?

At present it is not at all clear that significant environmental damage is being caused by ecosystem acidification. While certain sensitive[5] lakes and streams in the Northeast have apparently suffered as a result of acidification, no conclusive evidence exists to support the hypothesis that acid deposition has adversely affected forests,[6] soils,[7] crops,[8] or human health.[9]

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[4] 125 Cong. Rec. S16198, col. 2 (daily ed. Nov. 8, 1979) (emphasis added).

[5] As the Province of Ontario has noted, acidity "damages aquatic life in lakes and streams only in areas where there is very little capacity in the soils and rock to neutralize the acid." Ontario Ministry of the Environment, The Case Against Acid Rain 20 (October 1980).

2. Is Ecosystem Acidification Caused Primarily By *Precipitation Acidity?*

Although proponents of emission reductions routinely assume that precipitation acidity is primarily, if not exclusively, responsible for aquatic ecosystem acidification the validity of this assumption has not been demonstrated. The aquatic ecosystems that have exhibited signs of acidification--primarily poorly buffered lakes and streams in the Northeast--are frequently exposed to a variety of acidifying influences, each of which may play a significant role in determining pH levels.[10]

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[6] *See* National Council of the Paper Industry For Air and Stream Improvement, *Acidic Deposition and Its Effects on Forest Productivity* 40, 42, 58 (January 1981). As Senator Mitchell has recognized, the conclusions voiced by paper company representatives carry special weight with respect to forest productivity, since a reduction in growth could seriously affect the industry. See 127 *Cong. Rec.* S9085, col. 1 (daily ed. July 31, 1981).

[7] "The Debate Over Acid Precipitation: - Opposing Views - Status of Research", Government Accounting Office (September 11, 1981) at 8-10.

[8] ALS Associates, *The Effects of Ozone/Oxidant and Acid Rain on Agricultural Crops* 3-2 (1981) (prepared for Congress' Office of Technology Assessment).

[9] GAO Report at 11-12.

[10] ALS Associates, *The Effects of Acid Rain on Terrestrial and Aquatic Ecosystems* (1981) at 3-11, 3-15.

3. Would reductions in emissions significantly remedy the harm allegedly resulting from acid deposition?

The most serious uncertainty associated with various emission reduction proposals is the enormous doubt as to whether such reductions would significantly alter the pH of rainfall at significant distances downwind. As Dr. Ralph Perhac of the Electric Power Research Institute (EPRI) has stated:

> What if, for example, under some particular atmospheric condition only 20% of the sulfur in the air could get into rain drops? Under that situation, we could remove most of the sulfur and still have no effect on the acidity of the water. . . [U]ntil we know how acid rain actually forms . . . we will not know what effect increasing or decreasing powerplant emissions will have.[11]

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[11] Testimony of Dr. Ralph M. Perhac, Hearings on Acid Rain before the Subcommittee on Oversight and Investigations of the House Committee on Interstate and Foreign Commerce, 96th Cong. 2d Sess. 4-5 February 27, 1980.

Dr. Perhac's assessment of the difficulties involved in predicting the impact of emission reductions upon precipitation acidity is shared by Dr. Leonard Newman, an atmospheric scientist with Brookhaven National Laboratory. Dr. Newman recently concluded that:

> Since we have not identified the rate-limiting step in the incorporation of SO_2 into rain water, if that rate-limiting step is a catalyst (for example, carbon or a transition metal) then we might not reduce the amount of sulfate in the rainwater by simply reducing the amount of SO_2 in the air.

Newman, Acid Rain and the Atlantic Salmon 35 (paper delivered at conference sponsored by the International Salmon Foundation, November 22-23, 1980).

Subsequent studies serve to underscore this point. Researchers at Rensselaer Polytechnic Institute have recently analyzed precipitation pH in the Adirondacks in an attempt to evaluate the relationships between rainfall acidity and concentrations of sulfates and nitrates in precipitation. Data collected over a three year period indicate that substantial changes in sulfate and nitrate levels have only modest impacts on pH--thus casting serious doubts as to whether dramatic reductions in anthropogenic SO_2 and NO_x emissions could significantly alter precipitation pH. In testimony prepared for House hearings on acid rain, Dr. Robert Brocksen of EPRI commented on the implications of the RPI study:

> Based upon this relationship [between precipitation pH and sulfate and nitrate levels], we can calculate the change in precipitation pH as a function of the change in sulfate and nitrate concentrations. We estimate that the precipitation pH on the average will change from 4.2 to 4.5 if both the nitrate and sulfate concentrations are halved by some means. If sulfate alone is halved, the precipitation pH may, on the average, change from 4.2 to 4.4. Another observation which can be made from RPI's data is that the snowfall samples contain much more nitric acid than sulfuric acid. Reduction of the sulfuric acid content alone may not change the snow acidity to any significant extent. (Emphasis added)[12]

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[12] Testimony of Dr. Robert Brocksen before the House Subcommittee on Health and Environment (October 2, 1981) (emphasis added).

The point is that at present we have no firm evidence that emission reductions will make rainfall less acidic or that they will have any significant affect on the process of aquatic acidification.

4. Would the Prospective Benefits of Emission Controls Be Overshadowed by the Accompanying Costs?

Even if there was sound evidence for concluding that emissions reductions would significantly reduce ecosystem acidification, a thorough evaluation of whether resulting environmental benefits outweighed the costs of those reductions would be necessary before any rational control decision could be made. The benefits of air pollution control cannot be considered in a vacuum. We believe that the environmental advantages of emission reductions beyond those necessary to attain the primary standards should be evaluated in light of attendant economic and energy costs.

5. Would Emission Reductions Represent the Most Cost-Effective Mechanism for Remedying the Harm Allegedly Resulting From Acid Precipitation?

If an examination of costs and benefits were to reveal that a regulatory program were justified, one last critical threshold question would still have to be addressed before that regulatory program was devised--the issue of cost-effectiveness. Before any emission reduction requirements are imposed alternative ameliorative measures should be explored in an effort to determine whether ecological impacts could be remedied through less expensive means. In light of our Nation's limited economic resources, it would make little sense to choose measures not destined to maximize the environmental benefits obtained from each dollar spent.[13]

II. SECTION-BY-SECTION ANALYSIS OF S.1706

S.1706, which was introduced on October 6, 1981 by Senator Mitchell and 11 other members of the Senate, would impose an immediate moratorium on any increases of sulfur dioxide (SO_2) and nitrogen oxide (NO_x) emissions in a 31 state region, and require a 10,000,000 ton reduction in SO_2 emissions in that region within ten years after enactment. We believe these requirements are premature, irrational and punitive. They are premature because, as discussed previously, there is no firm evidence that they are necessary or that they will result in any significant environmental benefit. They are irrational because they would impose deadlines which obviously can't be met and because they fail to allow for reanalysis of the need for emissions reductions prior to their implementation. They are punitive because they tend to single out the utility industry specifically and the midwest in general and impose on them truly enormous costs.

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[13] A recent analysis of lake acidification in Europe suggests that mitigation measures aimed directly at lake pH--such as the addition of alkaline material--could constitute a potentially far more cost-effective strategy than the imposition of emission control requirements. *See* Barnes, *Acid Rain-An International Concern*, 30 J. Air Pollution Control Ass'n., 1089 (1980). Experimental liming programs undertaken by New York State and Ontario confirm the potential success of such an approach. *See*, Ember, *Acid Pollutants: Hitchhikers Ride the Wind* 59 Chem. & Engineering News 22 (September 14, 1981) (statement of New York State biologist Martin Pfeiffer); *Ontario Report*, *supra* note 7 at 22. The results of studies conducted in Ontario are particularly enlightening. After reviewing the impact of a liming program instituted at an acidified lake north of Sudbury, the Province of Ontario has concluded that:

> [t]he pH was restored to normal over a two-year period of time . . . [and] indications are that the treatment will be successful in restoration of the fishery. Therefore, the results of some experiments are making biologists more optimistic about liming programs.

Id. at 22.

Among the specific issues raised by S.1706 are seven that we find especially troubling: (1) the arbitrary nature of the emissions moritorium and the 10,000,000 ton SO_2 rollback requirements; (2) the enormous economic, employment and energy impacts of the bill; (3) the unreasonableness of the procedures to be followed in the event states fail to submit an emission reduction plan (or EPA fails to act upon the plans) within the time allotted; (4) the treatment accorded by the bill to sources not yet in operation; (5) the unnecessary restraints imposed by the bill on the flexibility states would be allowed in determining how to achieve emission reductions; (6) the inequitable nature of the emission reduction burden thrust upon the electric utility industry; and (7) the failure of the bill to address how installation of equipment necessary to comply with the required emissions reductions will be financed.

A. Section 181: The Identification of Acid Deposition Impact Regions

Section 181 of the Mitchell bill creates an acid precipitation impact region made up of 31 states which border on or are east of the Mississippi River. It also requires EPA to determine whether additional impact regions should be established throughout the remainder of the country. In drawing the geographic boundaries of such regions, two considerations should be kept in mind. First, the stringent emission reduction requirements imposed by S.1706 could dramatically affect the operations of any source in the 31 state impact region. Yet, despite the importance that the bill attaches to a state's inclusion in or exclusion from the region, the legislation designates the region through legislative fiat, rather than providing for a state-by-state evaluation of impact region coverage. We believe that any legislation should direct EPA to consider the issue through informal rulemaking to ensure that the borders of the initial region (and subsequent regions, if any) are properly drawn. The bill could easily accomplish this by granting EPA authority to devise the initial region pursuant to the rulemaking provisions of § 307(d) of the Clean Air Act.[14]

Second, S.1706 currently provides no guidance as to the criteria that should govern an impact area designation. If EPA is granted the authority to create such regions, Congress should establish substantive criteria[15] to be considered by EPA in determining whether designation is warranted.

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[14] By retaining power over the designation of additional regions, Congress could examine the propriety of EPA action in developing the initial region and, if necessary, establish remaining regions through legislative action.

B. Section 182(a): Moratorium on Increases in SO_2 and NO_x Emissions

1. Effective date of the moratorium

The Mitchell bill adopts an unusual approach with respect to the implementation of the prohibition on emissions increases contained in section 182(a). Instead of applying the provision as of the date of its enactment, the bill stipulates that the measure would be deemed effective *retroactive to January 1, 1981.* As a result, emission increases that occur between January 1, 1981 and the date of enactment would have to be offset immediately after passage of the bill. We believe that the retroactive establishment of an emission *reduction* requirement under the guise of a moratorium would be particularly unfair to source owners and state officials who had acted in reliance upon the law in existence in the interim.

2. Treatment of Sources Not Yet in Operation

Under the terms of the bill, the moratorium *cum* reduction applies equally to existing facilities, and sources not yet in operation. Emissions from the former (as of January 1, 1981) are in effect grandfathered; the cap only applies to subsequent SIP relaxations or permit modification requests. In contrast, the moratorium precludes any increase in emissions resulting from sources not in operation by January 1, 1981--thus effectively prohibiting industrial growth in areas where offsets are unavailable.[16]

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[15] The criteria could require examination of data relating to current levels of precipitation pH, projected emission trends, buffering capacity of ecosystems in the prospective region, etc.

The discouragement of new source construction makes little sense in light of the fact that major new sources (1) are subject to stringent emission limitations, (2) enable owners to increase productivity and energy efficiency, and (3) could ameliorate unemployment problems in economically distressed areas of the Northeast and Midwest. We believe new sources should be exempt from any moratorium on emissions increases.

The moratorium similarly places significant restraints upon utilities planning to convert to coal as a means of reducing foreign oil consumption. As with sources not yet in operation, prospective conversions resulting in significant emission increases would not be allowed unless offsets were available. Since the 10,000,000 ton reduction requirement would leave offsets in very short supply, conversions could prove prohibitively expensive, and in certain cases might be precluded altogether.

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[16] The problem would be most acute with respect to SO_2 emissions. The obligation could pose particularly severe problems for source owners who do not have a ready supply of intra-source offsets. Evidence compiled by the National Commission on Air Quality (NCAQ) indicates that inter-source offsets are already in short supply--a situation that could only be exacerbated by the bill's unprecedented emission reduction requirement. The Commission concluded that "[t]here is substantial evidence that sources that must obtain offsets from other companies will not generally be able to acquire them" in the absence of local or state government intervention. The National Commission on Air Quality, To Breathe Clean Air, 3.4-47 (1981) (emphasis added).

The moratorium could prove particularly devastating to ratepayers that have had to pay the costs of emission reductions achieved through reliance upon low sulfur oil. Utilities attempting to convert to coal in response to ratepayers' needs and national energy policies may be unable to do so as a result of the moratorium, since the potential for intra-source offsets in states such as Vermont, New Hampshire, Maine, Rhode Island, and Connecticut is quite limited.

In light of the regional economic and national energy considerations that militate strongly in favor of oil reduction, we recommend that the bill exempt coal conversions from the moratorium.

3. Minor source exemption

Under section 182(a) of the Mitchell bill, the moratorium's offset requirement would only apply to "significant" emission increases at "major" sources within the impact region. The moratorium itself, however, covers emissions from all stationary sources within the region. As a result, although minor sources would not be required to offset emission increases--a windfall of significant proportions--states would have to ensure that such emission increases were offset as part of the bill's emissions cap. The *de facto* exemption for minor sources undermines the bill's attempt to maintain the status quo, and unfairly imposes the costs of compliance exclusively upon major sources.

C. Section 182(b): The Ten Million Ton Sulfur Dioxide Emission Reduction

1. The nature and origin of the reduction requirement

Senator Mitchell's bill imposes truly massive emission reduction requirements upon sources in the Eastern United States.

Preliminary results of an analysis of S.1706 being done for EEI indicate that in 1979, stationary sources in the 31 state region specified by the bill emitted approximately 23 million tons of sulfur dioxide. Thus the bill would require that emissions from sources in this region be reduced by 44 percent, exclusive of emissions increases attributable to new source construction, modifications, coal conversions and SIP revisions generally. Table 1 demonstrates the magnitude of these emissions reductions on a state by state basis.[17]

In view of the extraordinary magnitude of the emission reduction requirement imposed by S. 1706, compelling justifications should exist to support its imposition. Yet when asked recently[18] the basis for the 10,000,000 ton figure, Senator Mitchell candidly acknowledged that it was "arbitrarily" chosen. In light of our present inability to relate changes in precipitation chemistry to emission reductions it is not surprising--although certainly disturbing--that the requirement was selected in such a manner. As EEI has repeatedly emphasized throughout the acid rain debate, it defies logic to mandate emission reductions without a clear understanding of what the benefits of such requirements would be.

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[17] Preliminary Analyses of the Impact of the Mitchell Bill, ICF, Inc. (October 22, 1981).

[18] Testimony of Senator George Mitchell in Hearings on Acid Rain Before the Subcommittee on Health and Environment of the House Energy and Commerce Committee (October 20, 1981) (transcript at p. 23) (hereinafter cited as Mitchell testimony).

TABLE 1
ANALYSIS OF MITCHELL BILL

SUMMARY OF REQUIRED EMISSION REDUCTIONS OF
SULFUR DIOXIDE IN THE ARMS REGION

Region/State	Distribution of Percent Reduction 1/	Total Reduction 2/ (Thous. Tons)	Total Sulfur Dioxide Emissions 3/ (Thous. Tons)	Percent Reduction Required in Total Emissions 4/
New England				
Connecticut	--	--	104.3	--
Maine	0.07	6.69	64.8	10.32
Massachusetts	0.77	76.54	297.3	25.70
New Hampshire	0.45	45.01	86.2	52.20
Rhode Island	--	--	18.8	--
Vermont	*	0.24	7.9	3.04
Total	1.28	128.49	579.3	22.18
Middle Atlantic				
New Jersey	0.53	52.72	305.8	17.24
New York	3.03	302.75	1,024.8	29.54
Pennsylvania	8.15	815.26	1,945.8	41.90
Total	11.71	1,170.74	3,276.4	35.73
South Atlantic				
Delaware	0.02	2.99	190.3	1.57
District of Columbia	--	--	18.4	--
Florida	3.30	330.17	821.8	40.18
Georgia	3.81	380.76	740.2	51.45
Maryland	1.08	107.55	328.0	32.79
North Carolina	2.01	200.63	502.2	39.95
South Carolina	1.13	113.25	272.9	41.50
Virginia	0.90	89.73	304.8	29.44
West Virginia	5.28	528.47	966.0	54.71
Total	17.54	1,753.55	4,144.6	42.31
East North Central				
Illinois	8.84	884.08	1,955.6	45.21
Indiana	10.17	1,017.30	2,117.8	48.04
Michigan	4.55	455.29	1,106.1	41.16
Ohio	16.06	1,606.04	3,125.8	51.38
Wisconsin	3.13	313.05	660.4	47.40
Total	42.76	4,275.76	8,965.7	47.69

See footnotes at end of table.

TABLE 1
(Cont'd.)

SUMMARY OF RQUIRED EMISSION REDUCTIONS OF
SULFUR DIOXIDE IN THE ARMS REGION
(Thousand Tons)

Region/State	Distribution of Percent Reduction 1/	Total Reduction 2/ (Thous. Tons)	Total Sulfur Dioxide Emissions 3/ (Thous. Tons)	Percent Reduction Required in Total Emissions 4/
East South Central				
Alabama	2.83	283.25	738.7	38.34
Kentucky	7.20	719.54	1,227.9	58.60
Mississippi	0.85	85.39	198.5	43.02
Tennessee	5.73	573.20	1,127.8	50.82
Total	16.61	1,661.38	3,292.9	50.45
West North Central (ARMS)				
Iowa	1.57	157.34	349.1	45.07
Minnesota	0.87	86.95	327.5	26.55
Missouri	7.20	719.57	1,374.6	52.35
Total	9.67	963.86	2,051.2	46.99
West South Central (ARMS)				
Arkansas	0.20	20.37	91.4	22.29
Louisiana	0.26	25.86	312.7	8.27
Total	0.46	46.23	404.1	11.44
Total ARMS Region	100.00	10,000.0	22,716.0	44.02

1/ Distribution of percent reduction from Table 5.

2/ Calculated by taking percent reduction from column 1 times 10 million tons.

3/ Total sulfur dioxide emissions from stationary sources from Table 1 (state-by-state totals from Appendix A).

4/ Percent reduction in total sulfur dioxide emissions equals total reduction in tons from column 2 divided by total emissions from column 3.

2. The Costs of the Reduction Requirement

Although the costs occasioned by the Mitchell bill's 10,000,000 ton of SO_2 reduction requirement would be enormous, the bill offers little indication that those costs were seriously considered. At hearings on October 20 before the Health and Environment Subcommittee of the House Committee on Energy and Commerce, Senator Mitchell estimated that his bill would cost industry in the neighborhood of $2.8 billion annually, which is equivalent to nearly $30 billion over the next decade. While we have not yet completed an analysis of the full economic impact of S.1706, a brief description of the likely magnitude of those impacts will illustrate the basis for our concern.

a. Capital Costs

The institution of a 10,000,000 ton SO_2 reduction requirement would require source owners to examine a broad variety of control measures in an effort to minimize emission reduction costs. Although in certain circumstances sources may elect to shift fuels, compliance with an emissions rollback of this size would clearly necessitate considerable capital expenditures. Major sulfur dioxide emitters could, for example, be forced to meet reduction requirements through the installation of flue gas cleaning devices, such as scrubbers or soda ash injection systems. Such controls are enormously expensive, particularly when retrofitted at existing facilities. There is little doubt that widespread scrubbing would be required to meet the emission reductions mandated by the bill. Recent estimates indicate that the capital costs alone of scubber retrofit would be staggering. The Department of Energy (DOE), for example, has estimated that the capital costs of retrofitting the 50 largest SO_2 emitters east of the Mississippi would exceed $12 billion. DOE's estimates are consistent with figures cited by the Environmental Law Institute ($14.8 billion) and the General Accounting Office ($7-18 billion)[19] and these estimates are undoubtedly conservative.

The installation of scrubbers would also result in substantial operating and maintenance costs and a yearly "energy penalty" stemming from the electricity required for their operation.

b. Fuel costs

Compliance with the emission requirement would force most major sources to reexamine current fuel purchasing practices and reassess future fuel acquisition plans. The legislation would likely result in shifts by fossil-fuel burning sources to lower sulfur coal and, whenever possible, continued operation of oil and gas-fired facilities.[20/] Fuel costs borne by utility, industrial, commercial and residential consumers would rise as a result of (1) the premium typically charged for lower sulfur fuels, (2) price escalation that would occur with rising demand, and (3) the additional processing costs (transportation charges, extraction taxes, etc.) associated with the procurement and delivery of lower sulfur fuels.

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[19] The Environmental Law Institute's (ELI) estimates were based upon data generated in EPA's ongoing Acid Rain Mitigation Study and appeared in an ELI report submitted to the National Commission on Air Quality. Environmental Law Institute, Institutional Aspects of Transported Pollutants: An Examination of Strategies for Addressing Long-Range Air Pollution Problems 32 (February 1981) (hereinafter cited as ELI Report).

The GAO Report cites both the ELI figures, and estimates compiled by the Department of Energy's Morgantown Energy Technology Center. General Accounting Office, The Debate Over Acid Precipitation, App. III at 40 (September 1981).

c. Capital formation

The utility industry is currently experiencing severe financial problems.[21/] It has seen its sources of capital dry

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[20/] The sulfur reduction equipment thus may be inimical to vitally important national energy policies, since it fosters dependence upon imported fuels.

[21/] An extensive EPA-commissioned analysis of the economic impacts facing the industry--based only upon current environmental regulations--paints a grim picture of these problems:

> "During the 1970s, environmental regulations covering air, water, and solid wastes were strengthened substantially. During the same period, rapidly escalating fuel and construction costs have led to major increases in the price of electricity and, indirectly, to a marked decline in electric utilities' financial condition, as evidenced by wholesale declines in bond ratings and by stock prices well below their book values.

Temple, Barker and Sloane, Environmental Regulations and the Electric Utility Industry 5 (July 1981) (draft report)."

up and the costs of capital mushroom as interest rates soar. Spiralling payments on borrowed funds have further depleted cash, thus requiring additional borrowing and further increasing the costs of servicing corporate debt. The emission reduction requirements contained in S. 1706 would obviously compound these problems; the purchase of control equipment would further drain available capital,[22] and increases in fuel costs would divert valuable cash flow. Finally, companies forced to borrow heavily could find their bond ratings lowered, thus leading to escalation of interest rates beyond the increases that have recently occurred as a result of the general deterioration of the bond market.

d. Unemployment and regional economic dependence upon coal

In large areas of the Midwest and Appalachia, coal mining is an essential component of a healthy economy. During the past decade the demand for high sulfur coal has declined, relative to low sulfur coal, and as a result, certain areas within the region have experienced severe economic dislocation and are still reeling from unusually high unemployment. Senator Mitchell's bill will exacerbate these problems. The prospect of a rise in demand for lower sulfur coals located in the West and other parts of the East offers little solace for residents of regions already struggling as a result of sagging coal demand.

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[22] Ironically, capital acquisition problems stemming from the bill could lead to the postponement of new source construction, thus frustrating efforts to retire older, less well controlled facilities.

e. Increases in consumer electric rates

Proponents of emission reduction requirements often suggest that consumers would only be subjected to minimal increases in electric rates with the enactment of a major SO_2 reduction program. These advocates, however, often fail to indicate that the modest increases they cite (e.g., 2%) are arrived at by diluting the costs over large geographic regions, when in fact the bulk of the cost would be borne by relatively few ratepayers. At the House Acid Rain Hearings held on October 20th, for example, Ohio EPA Director Wayne Nichols testified that emission reduction requirements on a scale envisioned by S. 1706 could lead to rate increases of 15-20% in parts of Ohio--in sharp contrast to the "reasonable" 2% increase suggested by many in the environmental community.

D. Section 183(a): Calculation of Emission Reduction Requirements

1. Failure to consider non-utility emissions

Section 183(a)(1) of the Mitchell bill provides that only utility emissions are to be counted in compiling the region's emission inventory and in calculating the states' rollback requirements. In effect S. 1706 abandons any attempt to apportion emission reduction requirements equitably among the affected states, and instead provides a windfall to states whose SO_2 emissions are fortuitously not emitted by utilities. States in which SO_2 emissions are produced by industrial, commercial and residential boilers, would not be required to reduce emissions in an amount proportional to their contribution to regional SO_2 loading. For example, Maine's annual SO_2 emissions from industrial, commercial and residential fuel combustion are approximately 46,000 tons while its annual utility SO_2 emissions are approximately 10,000 tons. Yet only the utility emissions would be counted in determining emissions reduction requirements.

E. Section 183(b): State Implementation Plan Requirements

1. The inclusion of emission reduction requirements in SIPs

Under S.1706 source-specific emission reductions must be included in state implementation plans. EPA therefore must initially review the adequacy of each rollback plan, and pursuant to section 110(a)(3)(A) of the Act, subsequently approve any changes sought by individual sources.

We are concerned that the traditional source-specific SIP revision review required by section 110 could create unnecessary hurdles for sources after they have complied with reductions imposed as a result of S. 1706. The procedural delays incident to EPA review could, for example, seriously interfere with source owners' efforts to realign emission reduction responsibilities and take advantage of inter-source disparities in emission reduction costs. We therefore recommend that where EPA has approved a state's rollback program, inter-source trades should be exempted from EPA review if net emissions will not increase.

2. EPA review of state emission reduction

S. 1706 allows EPA only four months in which to review the adequacy of state emission reduction plans. EPA efforts to comply with the four month deadline would undoubtedly prove futile, since the Agency's review of the 31 SIP revisions would require informal rulemaking--a proceeding that typically lasts far longer than four months--involving the resolution of complex factual and novel legal issues. At a minimum, the process would entail (1) an evaluation of the adequacy of each state's rollback plan; (2) the formulation of a preliminary decision to approve or disapprove the plan; (3) *Federal Register* publication of the proposed rule and solicitation of public comments; (4) an analysis of significant comments and preparation of responses thereto; and (5) formulation of a final decision on the SIP, including the incorporation of any revisions necessitated by public comments.

If S. 1706 attached no practical significance to the Agency's failure to meet the four month deadline, concerns regarding the reasonableness of the review period would be largely academic. Unfortunately, however, EPA's failure to comply with the timetable could spawn a series of citizen suits and seriously handicap the Agency's ability to conduct its other business.

By providing that the Agency "shall" conduct its review within four months, S. 1706 would arguably impose a mandatory duty upon EPA. Under section 304 of the Act, the Agency's failure to perform a non-discretionary duty--notwithstanding its apparent impracticability -- constitutes grounds for citizen suit litigation. Thus if the bill were enacted, EPA could conceivably become embroiled in litigation whenever it failed to comply with the four month deadline.[23] We recommend that any legislation recognize the limited nature of EPA's resources and avoid establishing timetables destined to provoke litigation and trigger statutorily imposed emission reduction requirements.

F. Section 184: Federally Imposed Emission Limitations

1. The statutory imposition of system-specific emission limitations

Sources located in states that fail to devise emission reduction plans or that fail to receive expeditious EPA approval of the plan receive harsh treatment under section 184 of S. 1706. If a state fails to submit a rollback plan within two years after enactment, or if EPA neglects to act upon the plan within 4 months after receiving it, all utilities within the state will be required to comply with a system-wide 1.2 lbs./MBtu average emission rate. The federal emission limitation philosophy embodied by section 184 represents an unjustifiably punitive and potentially far more expensive approach than that embodied by the bill's 10,000,000 ton rollback program. We believe it should be eliminated from any consideration by this Committee.

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[23] Environmental groups have demonstrated little reticence in seeking judicial sanctions aimed at requiring EPA to comply with statutory deadlines--however unrealistic. See, e.g., Sierra Club v. Gorsuch, No. 81-0094 (D.D.C. filed Jan. 14, 1981)(designed to force EPA to promulgate stack height regulations); Sierra Club v. Gorsuch, No. 81-2436 (N.D. Cal. filed June 16, 1981)(designed to force EPA to issue hazardous pollutant regulations for radionuclides); Friends of the Earth v. Costle, No. 79-2311 (D.C.C. November 5, 1979)(litigation resulting in settlement agreement requiring promulgation of final visibility protection rules).

a. Targeting of the utility industry

The statutory emission restrictions established in section 184 inexplicably exempts all sources from coverage except electric generating facilities. We object to this clearly discriminatory treatment of utilities and utility ratepayers. First, the singling out of the electric utility industry constitutes a repudiation of the bill's central premise that SO_2 reductions are essentially fungible, and that costs of control should therefore be minimized whenever possible. Section 184 instead imposes reduction obligations in a manner that ignores the economies that could be achieved by a broader apportionment of the reduction obligation. Second, the bill provides major non-utility emitters with a windfall--a complete exemption from any emission reduction requirement--whenever the state or EPA fails to comply with the patently unrealistic schedule set forth in § 184.

b. System-wide emission limitations

The federal emission ceiling proposed by S.1706 would drastically curtail inter-source trading by prohibiting emission reduction exchanges between industries and between different systems within the utility industry. Control requirements would be imposed on each utility system within the state, without any provision for source-specific analyses of the relative cost and feasibility of emission reductions. In effect, the ceiling constitutes an explicit repudiation of cost-effectiveness.

c. Let the punishment fit the crime

The uniform emission standard approach evokes serious concerns apart from its inherently discriminatory nature and its assault upon the principles of flexibility and cost-effectiveness. In a curious juxtaposition of crime and punishment, the ceiling imposes a severe penalty upon the utility industry in retaliation for actions or lack thereof of state or federal officials. Instead of instituting meaures designed to address the failure of such officials to act, the bill adds potentially enormous costs to the emission reduction requirement by drastically restricting the emission control measures that may be instituted. We strongly recommend that this illogical approach be abandoned, and that any legislation contain the approach Congress has already embraced in an effort to combat analogous state inaction under §110(c)(1) of the Act. Essentially that section authorizes EPA to prepare state plans to ensure compliance with the ambient standards if states themselves fail to devise SIP provisions, and through §§ 304 and 307, allows citizens to intervene if EPA action is inadequate. In the same manner, the Mitchell bill should simply allow EPA to carry on in the state's stead if the state fails to act.[24] EPA could then formulate SIP provisions consistent with the state's required reduction--after conducting hearings as required under §110(c)(1)(C)--in a manner designed to minimize emission control costs and preserve emission reduction alternatives.

G. Section 185(b): Inter-Pollutant Emission Reduction Exchange

1. The substitution concept and the reduction ratio

We support the substitution concept embraced by section 185(b) of S.1706. Although we disagree with the premise that additional emission controls should be imposed, we believe that if any legislation calling for emissions reductions is enacted, decreases in SO_2 and NO_x should be treated interchangeably.

We do not subscribe to the view that the NO_x/SO_2 reduction ratio must exceed one. The bill offers no evidence to support its implicit assertion that NO_x reductions should be viewed as less valuable than SO_2 reductions. Yet the rejection of equivalency would clearly skew control efforts towards sulfur dioxide, thereby interfering with sources' efforts to minimize control costs through reliance upon NO_x reduction measures.

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[24] Senator Moynihan's bill essentially adopts such an approach. See S. 1709 at § 185(a)(2).

2. Mobile source emission reduction credit

It is not clear whether S. 1706, in providing credit for NO_x emission reductions, requires that only decreases from stationary sources may be counted. As a result, it is unclear whether reductions achieved through compliance with mobile source controls may be relied upon by States in partial fulfillment of the bill's offset and emission reduction requirements.

We do not believe that credit should hinge upon the origin of the emission reduction. States whose citizens are forced to underwrite the costs of emission reductions--whether from mobile or stationary sources-- should be entitled to credit. The manner in which reductions are achieved is irrelevant; in either event total loading would decline and the purposes of the bill would be served.

H. Sharing The Costs of Reductions

In analyzing S. 1706, we have focused our attention upon two major issues: first, the advisability of enacting any emission control program, and second, the feasibility of the specific requirements established in the bill. If Congress does ultimately decide to enact emission control measures, a third key question will arise: how should the costs of control be apportioned? Although S. 1706 does not address the "who pays" issue, we believe that it must be considered in conjunction with any substantial emission reduction proposal.

Even if one assumes that controls are warranted, it hardly seems equitable to inflict the costs of an emission reduction program upon sources that are located in states destined to obtain relatively little of the alleged benefit from the required reductions. In light of this, we recommend that any acid rain legislation enacted by Congress address the issue of how the affected sources would raise the funds necessary to pay for the pollution control equipment required to meet emissions reduction requirements and how the costs of raising those funds could be borne at least in part by those who will supposedly reap the benefits.

III. SECTION BY SECTION ANALYSIS OF S.1709

S.1709, which was introduced by Senator Moynihan the same day that Senator Mitchell introduced S.1706, also mandates massive SO_2 emission reductions from major stationary sources in the same 31 state region but approaches this end in a somewhat different fashion than S.1706. The Moynihan bill contains no immediate moritorium on SO_2 amd NO_x emissions and rather than the 10,000,000 tons reduction within 10 years required by the Mitchell bill, it would require approximately a 8,200,000 ton reduction in SO_2 emissions by the end of 1991.

Many of the comments on S.1706 in the previous section of my statement are equally applicable to the Moynihan bill. Rather than repeating them here, I will simply comment on those features of S.1709 which we believe merit additional comment.

A. Section 2: Statement of Findings

The "findings" contained in section 2 of S.1709, like those set forth in section 180 of the Mitchell Bill, ignore a host of uncertainties and conflicting evidence regarding ecological impacts. The most egregious examples of this include statements that acid precipitation 1) is responsible for the elimination of aquatic life in hundreds of lakes in the U.S. and thousands of lakes in Canada (§ 2(4)(A)); 2) contributes to heavy metal concentrations in public water supplies that often exceed recommended health standards (§ 2(4)(B)) and 3) is known to cause substantial economic loss through damage to buildings and monuments made of metal and calcareous stone (§ 2(4)(C)). These "findings" are not supported by fact and should be deleted.

B. Section 183: Emission Reduction Requirements

Like section 182 of S.1706, section 183(a)(1) of the Moynihan Bill establishes stringent emissions reduction requirements application to 31 states bordering on and east of the Mississippi River. Each state in the designated impact region would be required by the end of 1991 to reduce by 1992 SO_2 emissions from all major stationary sources by an amount equal to 85% of the 1980 emissions from all powerplants in that state that emit more than 50,000 tons of SO_2 per year and have an SO_2 emission rate greater than 3 lbs/MBTU. There are 15 states which would not be required to achieve any reduction in emissions under S.1709. As shown on Table 2, the formula contained in S.1709 for

TABLE 2

REQUIRED REDUCTIONS BY STATE UNDER THE MOYNIHAN BILL
(Thousand Tons)

	Calculated Reductions[a/] From Major Emitters	Maximum Required[b/] Reduction	Actual Required[c/] Reduction
New England			
Connecticut	--	13.35	--
Maine	--	5.25	--
Massachusetts	--	82.80	--
New Hampshire	44.17	53.02	44.17
Rhode Island	--	1.40	--
Vermont	--	0.20	--
Total			44.17
Middle Atlantic			
New Jersey	--	54.15	--
New York	50.66	251.35	50.66
Pennsylvania	798.30	971.70	798.30
Total			848.96
South Atlantic			
Delaware	--	27.45	--
District of Columbia	--	3.15	--
Florida	197.54	305.25	197.54
Georgia	397.18	480.90	397.18
Maryland	113.02	101.8	101.80
North Carolina	--	185.2	--
South Carolina	--	85.7	--
Virginia	--	91.1	--
West Virginia	632.14	610.42	610.42
Total			1,306.94
East North Central			
Illinois	612.11	1,144.2	612.11
Indiana	1,201.4	1,203.3	1,201.4
Michigan	459.16	291.0	291.0
Ohio	1,817.67	1,691.7	1,691.7
Wisconsin	154.46	381.9	154.46
Total			3,950.67
East South Central			
Alabama	65.21	361.12	65.21
Kentucky	812.74	531.60	531.60
Mississippi	53.56	71.4	53.56
Tennessee	635.02	590.85	590.85
Total			1,241.22

See footnotes at end of table.

TABLE 2
(Cont'd.)

REQUIRED REDUCTIONS BY STATE UNDER THE MOYNIHAN BILL
(Thousand Tons)

	Calculated Reductions[a] From Major Emitters	Maximum Required[b] Reduction	Actual Required[c] Reduction
West North Central (ARMS)			
Iowa	--	177.68	--
Minnesota	--	83.80	--
Missouri	789.08	846.15	789.08
Total			789.08
West South Central (ARMS)			
Arkansas	--	20.85	--
Louisiana	--	14.10	--
Total			
Total ARMS Region			8,181.04

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[a] Values taken from Table 1.

[b] Values taken from Tables 5 and 6.

[c] The value from either the first column or the second column, whichever is less.

calculating the required emission reductions ensures that its major impact will be borne by the remaining 16 states. In some cases the emission reductions required of states under the Moynihan bill would be greater than those required by Senator Mitchell's bill, in others they would be less. For example, under S.1709, the reductions required for Illinois would be approximately 612,000 tons while under S.1706, Illinois' requirement would be approxiomately 884,000 tons. Interestingly, under Senator Moynihan's bill New York would be required to reduce its SO_2 emissions by approximately 50,000 tons while under the Mitchell bill its requirement would be approximately 302,000 tons. While we have not yet completed our analysis of the economic impacts of S.1709, I think it fair to say that those impacts in the states affected will be similar to the costs I noted above in reference to S.1706. Those economic impacts will be severe.

1. No Moratorium

S.1709 does not impose an immediate moratorium on SO_2 and NO_x emissions. From this standpoint, therefore, we believe it preferable to Senator Mitchell's bill.

2. Flexibility

Although the formula for allocating emissions reductions requirements in S.1709 is based upon power plant emissions, the actual reduction obligation is applicable to all major stationary sources which emit SO_2. We agree with the fact, recognized by this section of the bill, that principles of cost-effectiveness and equity demand that no source category be singled out for exemption from emission reduction requirements.

3. The ceiling for emissions reductions

Section 183(a)(2) of S.1709 provides limits on the amount of emissions reductions required of any one state. If the annual average utility SO_2 emissions rate in the state in 1980 was greater than 2 lbs. per million Btu, the amount of reductions required could not exceed 75% of the gross annual 1980 SO_2 emissions from all fossil fuel fired utility plants. If the average emissions rate was below 2 lbs./MBTU, then the amount of the reduction required could not exceed 50% of those gross emissions. The effect of this provision is demonstrated by Table 4. We agree with the principle that no one state should be required to bear a disproporationate share of an emissions reduction requirement.

4. Unrealistic Deadlines Applicable to EPA

Like the Mitchell bill, section 183 of S.1709 imposes virtually impossible deadlines on EPA. Sections 183(c) and (d), for example, require EPA actions within 60 and 90 days after enactment, even though the underlying emission reduction requirements will not be applicable for more than ten years. These requirements could easily lead to pointless citizen suits under § 304.

C. Section 184: SIP Requirements

1. Unrealistic SIP revision schedules

Section 184 of S.1709 requires the preparation and submission of state plans within one year after enactment. At a minimum this step entails (1) the survey of emissions and calculation of reduction requirements by EPA under §§ 183(c) and (d); (2) extensive analyses by state officials to determine how best to comply with the obligation; and 3) lengthy state administrative proceedings to ensure proper public participation in and oversight of the process. The one year period specified by the bill is simply inadequate to allow all these tasks to be completed. Again, the bill simply sets EPA up for citizen suits under section 304.

2. Substition of NO_x Reductions for SO_2

Like the Mitchell bill, S.1709 requires that No_x emissions reductions may be substituted for SO_2 reductions only on a 2 for 1 basis. As I noted earlier there is no basis for this two for one requirement.

D. Section 185: EPA Authority

One of the more significant provisions of the bill is its explicit rejection of the 1.2 lb. systemwide cap adopted by Senator Mitchell's bill. Instead, under S. 1709 if a state does not revise its SIP in time or submits an inadequate SIP, SIP authority shifts to EPA -- thus preserving federal review authority and the ability to devise cost-effective emission reduction measures. We believe that the approach embodied in section 185 of S.1709 is far preferable to that contained in S.1706.

IV. Section by Section Analysis of S.1718

S.1718, which was introduced by Senators Dodd and Durenberger on October 7, 1981, would make substantial changes in sections 110 and 126 of the Act - the provisions currently governing transport of pollutants across state boundaries. It would amend section 110(a)(2)(E) to require that SIPs include provisions to ensure that emissions from a "source or sources" within one state do not "contribute to air pollution which may reasonably be anticipated to endanger public health or welfare in any other state." This is essentially the same provision as that found in section 3 of the Mitchell bill.

The Dodd bill also amends section 126 to specify the kinds of evidence the EPA Administrator may or may not consider in acting on petitions alleging interstate pollution. The Administrator would be forbidden to "require that the petitioner rely solely on modelling or other methodology previously approved by the Administrator for estimating interstate air pollution." And he would be required to consider:

1. the total loadings of any pollutant emitted from sources in the affected air quality control regions in each State subject to the petition,
2. reasonable estimates of the contribution to air quality problems in the petitioning State that come from sources outside the State,
3. the prevailing winds and other meteorological factors affecting the transport of any pollutant between the affected air quality control regions,

4. the comparative economic impact, including, but not limited to, the impact on jobs and potential for economic growth, in affected air quality control regions in each State subject to the petition of making such a finding or denying such petition, and

5. such other factors as the Administrator may establish by regulation.

Sounding a note of impatience for those who cannot do the impossible, S.1718 requires the Administrator to do all this and make his ruling within 120 days after the petition has been filed. If he does not, a petitioning State may bring a citizen's suit against him immediately. The court can dispose of the matter itself and "shall assess a civil penalty in the amount of $100,000 against the United States, to be paid to the petitioning State."

A. Amendments to Section 110(a)(2)(E)

Our major difficulties with the amendments to section 110(a)(2)(E) contained in S.1718 is their ambiguity. The phrase "contribute to air pollution which may reasonably be anticipated to endanger public health and welfare" is obviously intended by Senator Dodd to mean something other than interfering with primary and secondary standards in another state. But exactly what it does mean is unclear. While we do not believe that any such amendment to section 110(a)(2)(E) is necessary, we also believe that if Congress is going to address the issue it should clearly define its terms and not leave them for the courts to decide.

B. Amendments to Section 126(b)

1. Unreasonble deadlines

S.1718 requires the Administrator to take final action on section 126 petitions within 120 days of receipt. When coupled with the criteria for deciding on such a petition imposed by S.1718 this deadline becomes totally unreasonable. In essence, the bill simply asks for failure and guarantees that litigation will follow.

2. Criteria for decisionmaking

While we agree with S.1718 that economics should be considered by the Administrator in determining whether to grant or deny a section 126 petition, we believe the criteria imposed by the bill such as the use of "reasonable estimates" could result in decisions made on records that are less than adequate.

3. The penalty provision

In authorizing a petitioning state to file suit if the Administrator doesn't act on a section 126 petition within 120 days, providing that a court shall issue an order directing the Administrator to act, and authorizing the imposition of a $100,000 civil penalty to be paid to the state, the Dodd bill virtually guarantees litigation.

Mr. Chairman, Members of the Committee,

My name is Chris Farrand. I am a Vice President of Peabody Coal Company, the nation's largest coal producer with reserves and mining operations in the Midwest and West.

We appreciate this opportunity to provide the Committee with the results of a study that we have made of the effects of S. 1706, a bill designed to reduce the effects of acid precipitation by requiring a significant reduction in annual atmospheric loadings of sulfur dioxide (SO_2) in a 31-state region of the East, South and Midwest.

Peabody has undertaken a state-by-state analysis to determine the economic impacts of the mandated 10 million ton reduction in annual SO_2 loadings required in the legislation. Our estimate is that some 307 million tons of coal would be displaced, affecting some 170,000 mine-related jobs with an incremental consumer cost impact of $3.2 billion per year for increased fuel costs alone.

However, before I discuss the methods and detailed results of this study, I would like to make a few points about the theory of S. 1706. First, it should be said that SO_2 is not the sole precursor of acid precipitation. S. 1706 admits to oxides of nitrogen as another apparent source and obliquely suggests that there may be still others. Nevertheless, reductions of SO_2 emissions are the major focus of the bill, with only a discounted credit toward SO_2 reductions given for the incidental reduction of nitrogen oxide. In other words, the legislation assumes not only that SO_2 is the primary source of acid precipitation, but that it is the only source worth controlling, and that reductions in SO_2 emissions will decrease acid rain in the sensitive areas of the Northeast.

Scientific Questions

Recent scientific evidence, however, indicates that the processes that result in acid rain are far more complex than anything that has been dealt with in air pollution so far, and that it cannot simply be assumed that reducing SO_2 emissions will reduce acid precipitation. In this connection, I would like to provide the Committee with two statements prepared by Dr. Volker Mohnen, Director of the Atmospheric Sciences Research Center at the State University of New York at Albany, which are pertinent to the relationship between emissions and acid rain. The first is a statement which he presented on this subject at a House Subcommittee hearing in September of this year. The second is a statement which he presented at an EPA hearing in June 1981. While the EPA hearing was not concerned with acid rain as such, but rather with the question of a long-range transport relationship between SO_2 emissions in the Midwest and ambient levels of sulfates and total particulate matter in New York and Pennsylvania, Dr. Mohnen's statement provides much information that is also relevant here.

I am not a scientist and I cannot answer questions about Dr. Mohnen's studies and analysis, but I would like to briefly summarize his central points. Dr. Mohnen's basic conclusion, on the basis of the best evidence to date, including his own research, is that there is no linear relationship between emissions of the precursor gases, such as SO_2, and acid rain, and that a "source-receptor" relationship between high emission density areas and acid deposition cannot be established at this time. As he shows, while SO_2 in the atmosphere can obviously contribute to have acid rain, the occurrence and extent of acid rain are not significantly determined by the magnitude of upwind SO_2 emissions, but rather by other factors, such as meteorological conditions, that are not well understood. Thus, Dr. Mohnen concludes, science cannot at this time determine the effect that emission reductions in one area would have on acid rain in another area. Indeed, under his analysis, even a substantial reduction in SO_2 emissions, such as would be required under the proposed legislation, might well not result in any measurable reduction in acid deposition in the sensitive area. This bill, then, with all its adverse economic consequences, could turn out to have no beneficial impact in terms of reducing acid rain.

It is regrettable that Dr. Mohnen could not be here to discuss his work, but I understand that he will be providing a written statement to this Committee on S. 1706 next week. I urge you to review his efforts before the approach suggested in this bill is taken too far.

Economic Impact

My primary purpose here today is to discuss the economic impacts of S. 1706.

In preparing our analysis of this legislation, Peabody concentrated on the bill's effect on consumer costs, as well as the dislocations in mine-related employment and revenues which would result. Since the bill places virtually the entire burden for meeting the required annual SO_2 reductions on the utility and coal industries, we attempted to predict its impact based on the lowest cost utility sector response. For purposes of this analysis, we assume that in almost every case utilities will choose to substitute fuels rather than retrofit existing facilities with flue gas desulfurization (FGD) equipment in order to meet their SO_2 reduction quotas. Where higher sulfur coal is presently used, the utility will attempt to substitute lower sulfur fuel with comparable heat values. Where SO_2 reductions in oil-fired facilities are required, we assume there will also be a non-technological response.

Peabody's experience in the market tends to confirm this non-technological approach. The reasons for the utilities behavior are understandable from their perspective. First, it is difficult, costly and sometimes technologically impossible to retrofit complicated FGD equipment to an existing facility. In some cases, there is simply not enough space to add the equipment. From an operational standpoint, there are problems in reliability of unintegrated systems, as well as difficulties with sludge-handling and disposal systems for older plants. Finally, there is a difficulty in capitalizing a relatively expensive accessory for an existing plant with no increase in output -- especially for the capital-constrained utility industry. Furthermore, with older plants, such a retrofit is not cost effective.

Method of Analysis

In accordance with the provisions of S. 1706, Peabody analyzed the amount of SO_2 emissions each of the 31 states in the defined Acid Precipitation Region would have to reduce from sources currently emitting at a rate which exceeds 1.2 lbs. of SO_2 per million BTUs. We did this by determining total emissions in the region from such sources, the total emissions in each state from such sources, and then applying the ratio of the two emission levels as a percentage against the 10 million ton reduction as specified in the bill. This gave us the amount of reduction in SO_2 emissions each state would be required to achieve annually by 1990.

We then calculated what would be the new allowable SO_2 emissions for 1990 for each of the affected states. From this amount, we were able to determine the average SO_2 emission rate for each state, and therefore the quality of coal or oil which must be burned in order to achieve that average emission rate. From this threshold, we were able to measure the amount of coal which was "unacceptable" and which must be replaced by lower sulfur or "acceptable" coal or oil to achieve the required reductions.

Using 1980 data on the delivered costs of both higher sulfur and lower sulfur fuels in each state, we were able to determine the unit cost differential. This figure is based on the actual experience in the state, comparing weighted average delivered prices for both the "acceptable" lower sulfur fuel and the "unacceptable" higher sulfur fuel. Where no acceptable fuel was used in a state during 1980, we used cost data for the appropriate fuel delivered to an adjacent state.

This cost differential was then multiplied by the number of tons of substitute coal required measured on BTU-equivalent basis. The result is a dollar figure for each of the states affected by the legislation.

I should point out that this method of calculation does not account for the effects of economic growth during the intervening years until 1990 when the 10 million reduction in annual SO_2 loadings must be achieved. The bill is ambiguous about whether the requirement is to reduce emissions below the current level or below the projected 1990 level. If the mandated reduction is based on current levels of SO_2 emissions in the region, even more impacts would result as utility emissions would have to be cut further to accommodate growth in emissions from other sources. This point is extremely important in the Northeast where there is a limited amount of coal-fired generating capacity, and therefore a limited opportunity to effect reductions in emissions from powerplants to tradeoff against increases from other sources. The bill could constrain economic growth and coal conversion in the region.

One case in point is the recent conversion of the Brayton Point Generating Station from oil to coal. Because the location of the plant cannot accommodate FGD equipment, the plant would have to be reconverted to oil in order to permit Massachusetts to meet its SO_2 reduction quota. Furthermore, it is improbable that any further conversions could occur in the New England region. Since the average delivered price of oil to powerplants in the U.S. now exceeds the BTU-equivalent in coal by a factor of 3.8, there would be a considerable penalty imposed upon the consumers in the region.

There are a number of other factors which were not taken into account in Peabody's analysis of the economic impact of the legislation. I would like to describe some of the factors which would make the results we have derived appear to be very conservative:

Other Factors in Peabody's Analysis:

- No attempt was made to account for inflation. All cost estimates are in 1980 dollars.
- No measurement was made of the additional price effects due to sudden demand for limited supplies of low-sulfur fuels and limited transportation capacity to accommodate large-scale shifts in fuel sources.
- The analysis assumes that wherever possible low-sulfur coal of comparable heat value will be substituted. If substantially lower BTU coal is used, additional tonnage would have to be purchased.

- If low-sulfur, low-BTU western coals are substituted, boiler modification and particulate emission control equipment would have to be added to existing plants.
- The analysis calculates the amount of acceptable coal required for blending to the precise emission requirements. No margin of safety for coal variability is assumed.
- Weighted average values are used to determine each state's emission limit. In actual practice, tradeoffs between plants or even between utilities may be utilized to achieve cost efficiencies. However, some site specific cases could be far more costly. One midwestern utility has indicated that its estimates are approximately equal to the amount we ascribe to the entire state.

Consumer Cost Impacts of S. 1706

Using the aforementioned methods and assumptions, Peabody has calculated the fuel cost impact of the proposed 10 million ton reduction in annual SO_2 emissions to be an estimated $3.2 billion dollars per year. The impact on electricity consumers varies significantly from state to state, ranging from a high of $454 million annually in Indiana, to zero in some states. Consumers in each of eight states, including Ohio, Pennsylvania, Missouri, Kentucky, Illinois, Georgia and Alabama, will pay an extra $200 million or more yearly to achieve the mandated reductions. West Virginia follows closely with an estimated additional annual fuel bill of $194 million.

Employment Impacts

In addition to the consumer impacts, there are severe dislocations in coal mine and mine-related employment. Our analysis shows that some 307 million tons of coal valued at approximately $9 billion would be displaced to meet the SO_2 emission reductions established in the bill. This loss of high and medium-sulfur coal production would severely impact a number of large coal producing states such as Illinois, Ohio, Kentucky, Pennsylvania, West Virginia, Indiana, Missouri and Alabama.

While coal mine and mine-related employment would obviously rise in the low-sulfur coal producing regions in the country, an estimated 98,600 direct mining jobs would be lost in the Midwest and the high and medium-sulfur coal producing regions of Appalachia.

In addition to the direct mining jobs which would be lost because of these massive production shifts, indirect employment would also be affected. Using a normal multiplier of 1.5; the total employment loss would amount to approximately 188,000 jobs in the 12 producing states affected by the bill.

Hardest hit among the producing states are:

	Direct Mining Jobs Lost	Indirect Jobs Lost	Total
Ohio	7,826	11,739	19,565
Pennsylvania	14,961	22,441	37,402
Indiana	4,043	6,065	10,108
West Virginia	17,125	25,687	42,812*
Illinois	12,113	18,169	30,282
Alabama	4,046	6,069	10,115
Western Kentucky	8,976	13,464	22,420

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*Job losses in West Virginia may be offset in part by gains in low-sulfur producing areas of the state.

These job loss calculations are based on average coal productivity in each of the states. Obviously, the massive shifts in coal production would have other consequences as well, including lost income from both coal sales and coal-related employment, loss of state and local income and property taxes, and higher budgets for unemployment compensation and other social welfare programs.

Conclusion

Mr. Chairman, it is our contention that S. 1706 is an inappropriate solution to the problem of acid deposition for two basic reasons. First, the economic consequences of the legislation are unconscionably severe and far outweigh the benefits to be derived. By any set of assumptions, the impacts caused by this bill in terms of consumer costs, job dislocation, inflation and infrastructure difficulties are punitive. Those consequences are all the more distressing because they bear no assurance that any commensurate reduction in acid rain will occur as a result.

While the evidence of Dr. Mohnen and others suggests that acid precipitation may be far more dependent on factors other than SO_2, current law already deals with the question of SO_2 loadings by requiring all new coal-fired powerplants meet rigid emission limit standards. To impose requirements on existing facilities on the scale contemplated in this bill, rather than await their replacement with cleaner, newer plants, will result in massive and unnecessary economic disruption.

We believe the problem of acid rain deserves far more careful consideration than is evidenced in the approach suggested by S. 1706. We urge in the most strenuous terms that the Committee not proceed with this legislation.

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OCTOBER 1981
PAGE ONE OF TWO

ATTACHMENT A

PROJECTED 1980 COAL COSTS FOR S. 1706 1/

STATE	TOTAL SO$_2$ EMISSIONS GREATER THAN 1.2 LBS./MM BTU TONS X000 2/ COAL	OIL	TOTAL	REQUIRED REDUCTION IN TOTAL SO$_2$ EMISSIONS TONS X000 COAL	OIL	TOTAL	COAL GREATER THAN 1.2 LBS./MM BTU DISPLACED TONS X000	INCREASED COAL COST DUE TO DISPLACEMENT $ X000
Alabama	314.7	-	314.7	297.0	-	297.0	15,300.4	$289,353.2
Arkansas	-	3.1	3.1	-	2.9	2.9	-	-
Connecticut	-	-	-	-		-	-	-
Delaware	15.5	0.2	15.7	14.6	0.2	14.8	755.7	14,951.9
Florida	236.3	93.6	329.8	223.0	88.3	311.3	6,976.1	13,342.0
Georgia	444.6	3.2	447.8	419.7	3.0	422.7	17,762.0	215,890.7
Illinois	811.2	-	811.2	765.7	-	765.7	16,944.4	232,862.6
Indiana	1,354.9	-	1,354.9	1,278.9	-	1,278.9	29,300.9	454,858.3
Iowa	100.0	-	100.0	94.4	-	94.4	2,074.0	13,164.0
Kentucky	845.0	-	845.0	797.6	-	797.6	22,477.7	224,701.7
Louisiana	-	0.5	0.5	-	0.5	0.5	-	-
Maine	-	2.4	2.4	-	2.3	2.3	-	-
Maryland	97.9	7.9	105.8	92.4	7.5	99.9	5,534.9	24,809.1
Massachusetts	3.8	93.2	97.0	3.6	88.0	91.6	493.3	4,590.2
Michigan	227.8	-	227.8	215.0	-	215.0	5,255.1	28,498.8
Minnesota	89.6	0.7	90.3	84.6	0.7	85.2	8,410.8	115,224.2
Mississippi	62.9	25.1	88.0	59.4	23.7	83.0	2,004.8	41,088.7
Missouri	917.9	0.5	918.4	866.4	0.5	866.9	16,761.3	261,161.6

PAGE TWO OF TWO

STATE	TOTAL SO$_2$ EMISSIONS GREATER THAN 1.2 LBS./MM BTU TONS X000[2]			REQUIRED REDUCTION IN TOTAL SO$_2$ EMISSIONS TONS X000			COAL GREATER THAN 1.2 LBS./MM BTU DISPLACED TONS X000	INCREASED COAL COST DUE TO DISPLACEMENT $ X000
	COAL	OIL	TOTAL	COAL	OIL	TOTAL		
New Hampshire	33.9	9.9	43.8	32.0	9.3	41.3	955.4	17,820.5
New Jersey	40.0	1.9	41.9	37.7	1.8	39.6	2,103.4	23,617.9
New York	128.5	73.2	201.7	121.3	69.1	190.4	5,681.4	115,054.4
North Carolina	82.4	-	82.4	77.8	-	77.8	12,479.7	171,890.9
Ohio	1,704.8	0.2	1,705.0	1,609.2	0.2	1,609.4	41,616.8	254,599.3
Pennsylvania	1,082.0	-	1,082.0	1,021.3	-	1,021.3	39,082.4	352,563.2
South Carolina	96.2	6.4	102.6	90.8	6.0	96.8	6,198.5	86,908.7
Tennessee	633.2	-	633.2	597.7	-	597.7	20,640.5	71,537.0
Vermont	-	-	-	-	-	-	-	-
Virginia	8.9	9.0	17.9	8.4	8.5	16.9	2,107.0	(3,414.2)
West Virginia	594.7	-	594.7	561.4	-	561.4	18,361.7	170,762.3
Wisconsin	337.0	0.1	337.1	318.1	0.1	318.2	7,788.3	64,856.8
Wash., D. C.	-	-	-	-	-	-	-	-
TOTALS	10,263.6	335.8	10,594.8	9,688.0	312.6	10,000.0	307,066.5	$3,260,693.8

1/ Cost and Quality of Fuels for Electric Utility Plants, 1980 Annual, U.S. Department of Energy, DOE/EIA-0191(80), June 1981

2/ Emissions calculated from fossil fuel receipts to steam-electric units 25 MW or greater, 1980. Emission levels do not reflect the use of FGD equipment. Forty-six (46) scrubbers are currently in place in plants burning 7.8% of coal. At design efficiencies, these scrubbers would reduce emissions by approximately 6.5%.

OCTOBER 1981

APPENDIX

Incremental costs are based on differentials between weighted average 1980 delivered prices of acceptable coal and non-acceptable coal within each state multiplied by the number of tons to be displaced. For purposes of this study, acceptable coal is defined as coal of appropriate BTU and sulfur content which, when combusted, has the potential to produce SO_2 emissions of 1.2 lbs. per million BTUs or less. If no acceptable coal was delivered to the state in 1980, acceptable coal prices were based on weighted average 1980 delivered prices to an adjacent or nearby state as explained below. All prices are based on the weighted average of all coal deliveries of comparable coal quality to the state in the compliance or non-compliance category.

Alabama - Compliance coal prices were based on weighted average 1980 delivered prices for compliance coal to Mississippi from Colorado and Utah, and to Florida from Virginia and West Virginia.

Delaware - Based on deliveries to Delaware from West Virginia, and to New Jersey from Kentucky.

Georgia - Based on deliveries to Florida from Virginia and West Virginia.

Maryland - Based on deliveries to Delaware from West Virginia, and to Virginia from Kentucky, Virginia, and West Virginia.

Massachusetts - Based on deliveries to New Jersey from Georgia, Kentucky and West Virginia.

Minnesota - Based on an arithmetic average of deliveries to Iowa from Colorado and Wyoming.

North Carolina - Based on deliveries to Kentucky from Virginia and West Virginia.

New Hampshire - Based on deliveries to New Jersey from Georgia, Kentucky, and West Virginia.

New York - Based on deliveries to New Jersey from Georgia, Kentucky, and West Virginia.

Pennsylvania - Based on deliveries to Ohio from Pennsylvania, Tennessee, Virginia, and West Virginia.

South Carolina - Based on deliveries to Kentucky from Virginia and West Virginia, and to Florida from Virginia and West Virginia.

Tennessee - Based on deliveries to Ohio from Pennsylvania, Tennessee, Virginia and West Virginia.

Wisconsin - Based on an arithmetic average of deliveries to Iowa from Colorado and Wyoming.

EMPLOYMENT IMPACTS IN PRODUCING STATES

	TOTAL TONS OF COAL DISPLACED (X000)	WEIGHTED AVERAGE ANNUAL PRODUCTION PER WORKER	DIRECT MINING JOBS LOST	TOTAL JOBS LOST [1]
Alabama	12,289.4	3,038	4,046	10,115
Illinois	45,260.9	3,737	12,112	30,280
Indiana	24,677.8	6,123	4,043	10,108
Iowa	317.0	2,735	79	198
Western Kentucky	34,632.8	3,858	8,976	22,420
Maryland	1,067.2	2,676	396	990
Missouri	3,024.3	4,620	655	1,638
Ohio	31,382.0	4,010	7,826	19,565
Pennsylvania	46,289.4	3,094	14,961	37,403
Tennessee	6,492.6	2,621	2,477	6,193
Virginia	6,768.6	2,308	2,933	7,333
West Virginia	31,259.8	1,878	16,645	41,613
TOTALS	243,461.8 [2]		75,149	187,856

1/ Computed by multiplying direct mining jobs lost by 1.5 and combining direct jobs and indirect jobs.

2/ Remaining production losses of 63,604,700 tons occur in states outside the 31-state region and in Eastern Kentucky where no net loss in employment is expected.

ATTACHMENT C

THE CASE AGAINST ADDITIONAL ACID PRECIPITATION LEGISLATION

Legislation which mandates a specified reduction in sulfur dioxide emission loadings is unwarranted because:

1) There is no assurance that a reduction in SO_2 loadings will result in a decrease in acid rain;

2) The economic and social effects of a mandated reduction are likely to be severe; and

3) The problem [illegible] SO_2 loadings is largely self-correcting [illegible] time as newer, cleaner, more efficient powerplants are brought on line. Forcing a retrofit of existing facilities or displacement of local coal brings high cost and disruption.

- Best and most recent scientific evidence provides no assurance that a 50 percent or any mandated reduction in SO_2 emissions will result in a decrease in acid precipitation and sulfate levels in the northeastern states.

The best and most recent scientific evidence indicates that there is no linear relationship between SO_2 emissions from midwestern sources, the conversion of SO_2 into sulfates, and the resulting concentration of sulfates or acidic deposition hundreds of miles away in the northeast. While some reservoir of SO_2 must obviously be present to form sulfates, the recent evidence indicates that many other factors, particularly meteorological and photochemical parameters, are far more important than the magnitude of upwind SO_2 emissions in determining the appearance and level of acidic deposition in the northeast. Thus, even a significant reduction in SO_2 emissions from midwestern sources would most likely not result in a measurable reduction in acid deposition in the northeastern states.

This evidence is discussed in detail in statements of Dr. Volker Mohnen, Director of the Atmospheric Sciences Research Center at the State University of New York at Albany, and Dr. George Hidy, Vice President and Chief Scientist of Environmental Research and Technology, Inc., at a hearing conducted by EPA in June 1981.

Some of the recent findings discussed in these statements are as follows:

> Wilson, Mohnen, et al. (1980, 1981), through combining an analysis of wet deposition of pollutant-related ions over the eastern United States with trajectory analysis, found that deposition of the ions did not depend on whether the air masses had passed during the prior two days over midwestern regions or Canadian regions, but rather depended primarily on the volume of precipitation. After normalization for precipitation amount, there was no significant west-east gradient in the ion deposition, thus indicating that there is no linear relationship between midwestern SO_2 emissions and acidic deposition in the northeast.
>
> Samson (1980) found that sulfate concentrations at eight locations in the northeast correlated well with upstream stagnation, but that no consistent relationship was discernable with upstream SO_2 emission loading.
>
> Lioy, et al. (1981) found that the most significant components explaining the variation in sulfate levels at a site in West Virginia were meteorological and photochemical parameters and primary particulate emissions, with upwind SO_2 emissions explaining less than 6 percent of the variance.
>
> Wolff, et al. (1981) showed that the distribution of sulfate aerosol over the eastern United States depends upon complex processes and factors, e.g., ozone, beyond SO_2 emissions and wind direction.
>
> Granat (1978), analyzing data from the European Atmospheric Chemistry Network, found that an increase in sulfur emissions of 50 percent in Europe over a 10-year period did not lead to a measurable increase in sulfate wet deposition in the area covered by the network.
>
> Rodhe, et al. (1979), also using European data, found that the increase of the concentration of sulfuric and nitric acid in the air was significantly less than the increase in emission rates of SO_2 and NO_x.

- In the past, mandated reductions in sulfur dioxide have resulted in the dislocation of high-sulfur coal by low-sulfur coal.

Most of the coal mined in the midwest, including that mined by Peabody, has a relatively high-sulfur content.

The maximum sulfur content of the coal that a powerplant may burn is directly affected by the sulfur dioxide emission limitation applicable to it. When SO_2 emissions from powerplants have been required to be reduced to meet regulatory requirements, the plants have usually switched from high-sulfur to low-sulfur coal, and the economic impact on the respective high-sulfur coal producing areas has been significant. In 1979, Peabody conducted a study of the impact on high-sulfur coal demand caused by utilities complying with SO_2 emission limitations (Peabody Coal Company, High-Sulfur Coal Study, August 1979). It was estimated that during the period 1977-1980, approximately 43 million tons of high-sulfur coal was or would be displaced by low-sulfur coal. This equates to the loss of 12,000 direct mining jobs in the high-sulfur coal producing areas.

- Expectations are that further mandated reductions would have a similar adverse economic effect.

According to a recent proprietary study prepared by ICF Incorporated for Peabody and a number of other companies, the effect on high-sulfur coal demand resulting from a hypothetical additional requirement to reduce SO_2 emissions from all existing sources in a 31-state region in the east by 30 percent would cause, by 1990, an additional annual loss of 68 million tons of high-sulfur coal production in the supply regions of northern Appalachia (21.4) and the midwest (47.0) (ICF Incorporated, Coal and Electric Utility Market Assessment, Spring 1981). The ripple effect of these direct job losses could raise the total unemployment to 1.5 to 2 times the number of direct mining jobs lost.

- The problem of SO_2 loadings is largely self-correcting over time.

The new source performance standards (NSPS) for steam electric generating units requires the installation of the best technological system of continuous emission reduction. This has manifested itself into a regulatory requirement to remove between 70 and 90 percent of the possible SO_2 emissions from burning fossil fuel. Therefore, as older plants are retired over time, total SO_2 loadings will decrease. In 1979, ICF Incorporated, on behalf of EPA, estimated the decrease in utility emissions to be from 18 million in 1975 to 10 million in 2010.

- The impact of importing low-sulfur coal can be severe.

Utilities which purchase low-sulfur coal to displace local high-sulfur coal generally pass along the increased transportation charges to the consumer. The alternative of retrofitting an existing plant with a flue-gas desulfurization unit or scrubber requires case-by-case approval of the local utility commission. Hence, there is a bias toward the low-sulfur alternative. Moreover, the ultimate consumer cost of importing coal can be very high.

Peabody has calculated that the cost of substituting low-sulfur "acceptable" coal in an amount necessary to meet the 10 million ton reduction in annual SO_2 loadings called for in legislation now under consideration would exceed $3.2 billion annually. This figure assumes only coal substitution, not the capital costs associated with plant modifications or the retrofitting of flue-gas desulfurization or scrubber equipment on existing plants. The figure also does not reflect inflation, nor does it account for the effects of massive shifts in coal production and coal-related employment. Peabody estimates that as many as 188,000 jobs would be affected.

BEFORE THE
CONGRESS OF THE UNITED STATES
HOUSE OF REPRESENTATIVES
SUBCOMMITTEE ON NATURAL RESOURCES
OF THE
COMMITTEE ON SCIENCE AND TECHNOLOGY

STATEMENT OF VOLKER A. MOHNEN, Ph.D.

Director, Atmospheric Sciences Research Center
Research Professor, Department of Atmospheric Sciences
State University of New York at Albany

Sept 18, 1981

My name is Volker A. Mohnen. I hold a Ph.D. degree in physics, with a minor in meteorology and astrophysics, from the University of Munich. I am currently the Director of the Atmospheric Sciences Research Center and a Research Professor in the Department of Atmospheric Sciences at the State University of New York at Albany and am actively involved in research in the fields of air pollution, air chemistry and related subjects such as acid rain. I am the author of more than 120 publications and reports dealing with those subjects. My curriculum vitae is attached hereto.

I am presenting this statement at the invitation of the Honorable James H. Scheuer, Chairman of the Subcommittee.

Introduction

The Atmospheric Sciences Research Center operates a field station at Whiteface Mountain, in the middle of the Adirondack Mountains, that has been designated by the Department of Energy as the Rural Precipitation Chemistry Center. This station is part of the MAP3S/RAINE network and has measured precipitation quantity and quality on an event basis since the fall of 1976. In addition, the Atmospheric Chemistry Section of the National Science Foundation, supports for the past four years a variety of our research projects relating to acid rain in general and to the causes thereof in particular. The Center's research efforts are confined to "mechanisms research" as opposed to "effects research". To this extent we have focussed our attention to the measurement of wet deposition, the identification of chemical and physical mechanisms governing the appearance of acidic material (and pollution-related material in general) in precipitation and to the role of clouds, fogs and dews in the overall transport and transformation of gases that eventually yield sulfuric and nitric acid in precipitation.

In the following section I shall assess the overall results for wet deposition in the Eastern United States with particular emphasis on the impact of air masses that have passed over areas with significantly different sulfur and nitrogen emission densities. The main result is that a "source-receptor" relationship between high emission density areas and wet deposition of pollution-related ions cannot be established at this time.

I shall also briefly summarize and assess the atmospheric models that have been selected by working group 2 of the US/Canada work group on Transboundary Air Pollution for establishing source-receptor relationships. My main findings are that none of the models adequately and realistically incorporate the overall transformation of sulfur and nitrogen bearing molecules into acidic materials. These models assume a linear transformation which has not been confirmed in the field. To the contrary, recent field experiments indicate the existance of very complex, non-linear transformation pathways that ultimately lead to wet deposition, i.e., acid rain.

The following support material is available from ASRC upon request to provide detailed insight on the above findings:

1) ASRC Publication 796. Wet Deposition in the Northeastern United States. J. Wilson, V. Mohnen and J. Kadlecek. December 1980.
2) Wet Deposition as Observed by MAP3S. J. Wilson, V. Mohnen and J. Kadlecek. Accepted for publication in *Atmospheric Environment*. 1981.
3) An Analysis of Spatial Variability of the Dominant Ions in Precipitation in the Eastern United States. J. Wilson and V. Mohnen. Submitted for publication in the *Journal of Water, Air, and Soil Pollution*. 1981.
4) Acidity in Air and Water in a Case of Warm Frontal Precipitation. A.L. Lazrus, P.L. Haagenson, G.L. Kok, B.J. Huebert, C.W. Kreitzberg, G.E. Likens, V.A. Mohnen, W.E. Wilson and J.W. Winchester. Presented at APCA Conference, Philadelphia, PA. June 1981. Session # 13.

I am deeply indebted to Drs. Jerre Wilson and John Kadlecek for their help in preparing this statement.

Acid Precipitation in the Eastern United States

The measurement of free hydrogen ion concentration in precipitation (pH) is not a trivial measurement, and its interpretation requires detailed information on:

- sampling location
- chemical and physical conditions of the surrounding terrain or surface
- sampling collection procedure for precipitation
- sample handling, etc.

The diagram in Figure 1 attempts to illustrate some of the informational needs that must be included with the publication of a pH value. Most measurements are made today on a weekly basis (such as in the National Atmospheric Deposition Program--NADP) or on an event basis (such as in the Multistate Atmospheric Power Production Study--MAP3S). An event is defined by the beginning and the end of precipitation. Modern collectors are normally closed and open only during precipitation through an automatic triggering device. This procedure will minimize contamination that arises from dry deposition of dust and wet debris. Precipitation samples can be collected by ground collectors or airborne platforms. Rain that fell trhough the last few meters of the planetary boundary layer might be of different quality than rain that was collected at a considerable height above ground. A ground collector can be located over ocean or over land, above or below a vegetation canopy, or in an open field. Precipitation can be collected from above (mountain tops, etc.)

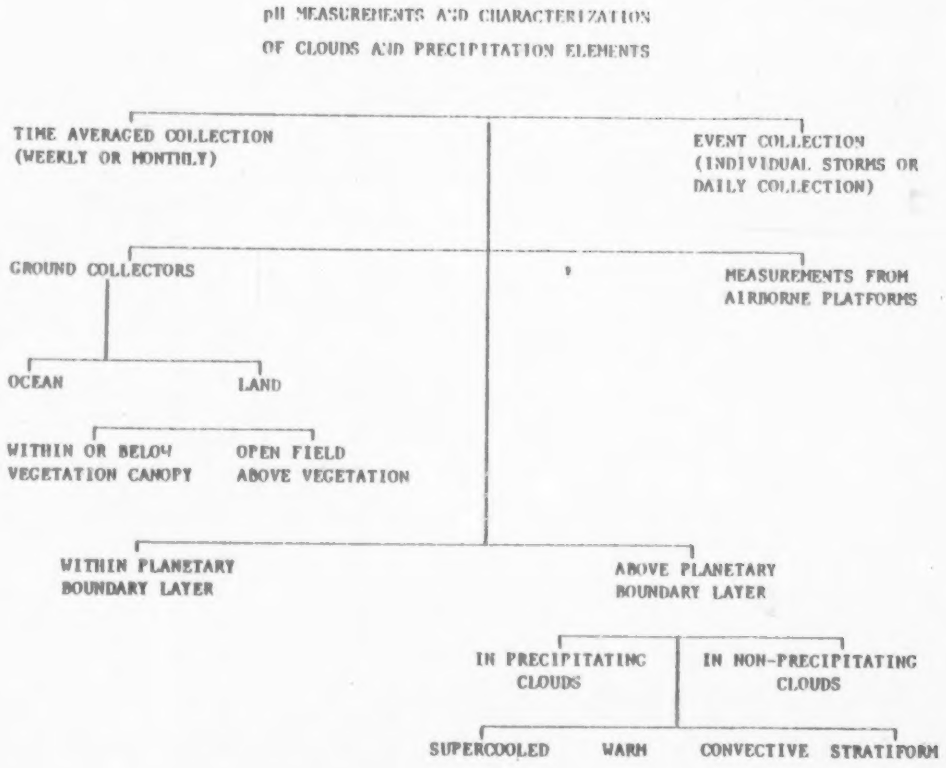

pH MEASUREMENTS AND CHARACTERIZATION
OF CLOUDS AND PRECIPITATION ELEMENTS
TIME AVERAGED COLLECTION (WEEKLY OR MONTHLY)
EVENT COLLECTION (INDIVIDUAL STORMS OR DAILY COLLECTION)
GROUND COLLECTORS
MEASUREMENTS FROM AIRBORNE PLATFORMS
OCEAN
LAND
WITHIN OR BELOW VEGETATION CANOPY
OPEN FIELD ABOVE VEGETATION
WITHIN PLANETARY BOUNDARY LAYER
ABOVE PLANETARY BOUNDARY LAYER
IN PRECIPITATING CLOUDS
IN NON-PRECIPITATING CLOUDS
SUPERCOOLED
WARM
CONVECTIVE
STRATIFORM

Figure 1. pH measurement classification.

or below the planetary boundary layer. Most networks today that collect precipitation for long-term monitoring are based on weekly or event-by-event sampling from ground stations that are located in an open field with no hearby obstacles.

The pH value obtained from such collection sites might have regional representativeness. All values analyzed and reported here originate from such networks. A very strict quality control procedure exists for both MAP3S and NADP. One should keep in mind that the pH itself is insufficient to characterize precipitation quality. It is very informative to divide the ionic constituents of precipitation into three categories or components:

- o Soil-derived minerals Ca^{++}, Mg^{++}, Fe^{3+}, silicate ions, etc.
- o Sea salt Na^+, Cl^-, $SO_4^=$, plus small amounts of K^+, Mg^{++} and Ca^{++}
- o Atmospheric conversion products from sulfur and nitrogen bearing molecules, i.e., $SO_4^=$, NO_3^-, in addition to NH_4^+ and Cl^- (from hydrochloric acid) and, obviously, H^+

The dominant source of data is the Multistate Atmospheric Power Production Pollution Study (MAP3S). In this ongoing study, precipitation chemistry data are obtained on an event basis beginning in 1976 for the original MAP3S collection sites of:

o Whiteface Mountain/New York	(WFM)
o Ithaca/New York	(ITH)
o Pennsylvania State University	(PEN)
o University of Virginia	(VIR)

In 1977-1978 four more stations were added to the network located at:

- o Champaign-Urbana/Illinois (ILL)
- o Lewis/Delaware (coastal site) (LEW)
- o Brookhaven, Long Island/New York (coastal site) (BRO)
- o Oxford/Ohio (OXF)

The location of all MAP3S stations is shown in Figure 2.

The basic precipitation collector used by the MAP3S network during 1977-1979 was a wet deposition-only type designed by Battelle Pacific Northwest Laboratory as shown in Figure 3. This collector allows a relatively large exposed collection area while minimizing splashing and turbulence. An enclosed chamber enables samples to remain refrigerated until their removal for shipment. (A HASL type collector has been used since then.)

Field site operators measure pH, conductivity and sample volume before shipment to Battelle Pacific Northwest Laboratory for complete analysis.

To insure that an ionic balance was maintained between the major ions $SO_4^=$, NO_3^-, H^+ and NH_4^+ throughout the three-year period, ions or pairs of ions were analyzed for correlation or degree of association.

Figure 4 shows the balance between the four dominant ions, $SO_4^=$, NO_3^-, H^+ and NH_4^+. The linear correlation coefficient of 0.95 for Whiteface Mountain indicates that a significant portion of the sulfate and nitrate could exist in the form of sulfuric and nitric acid and the appropriate ammonium salts.

The linear correlation can further be improved by removing the soil components, indicated by Ca^{++} and Mg^{++}, from the cation summation as shown in Figure 4a. The correlation of 0.98 suggests an extremely good ion balance exists whenever boundary layer influences such as soil components can be reduced.

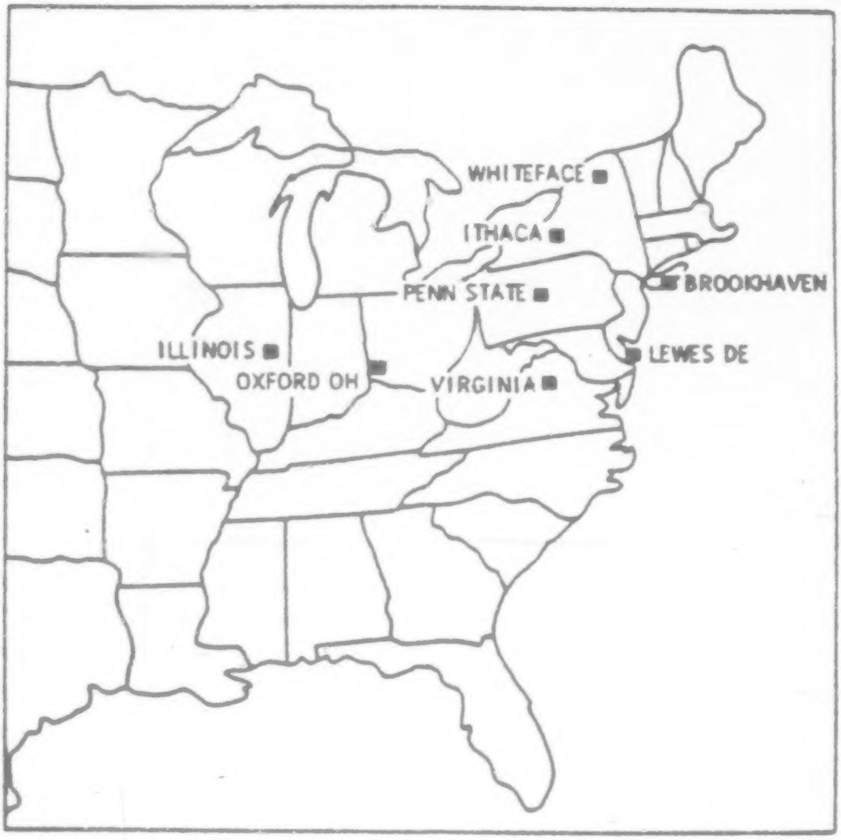

WHITEFACE
ITHACA
BROOKHAVEN
PENN STATE
ILLINOIS
OXFORD OH
VIRGINIA
LEWES DE

Figure 2. The MAP3S precipitation chemistry network site array. (MacCracken, 1979)

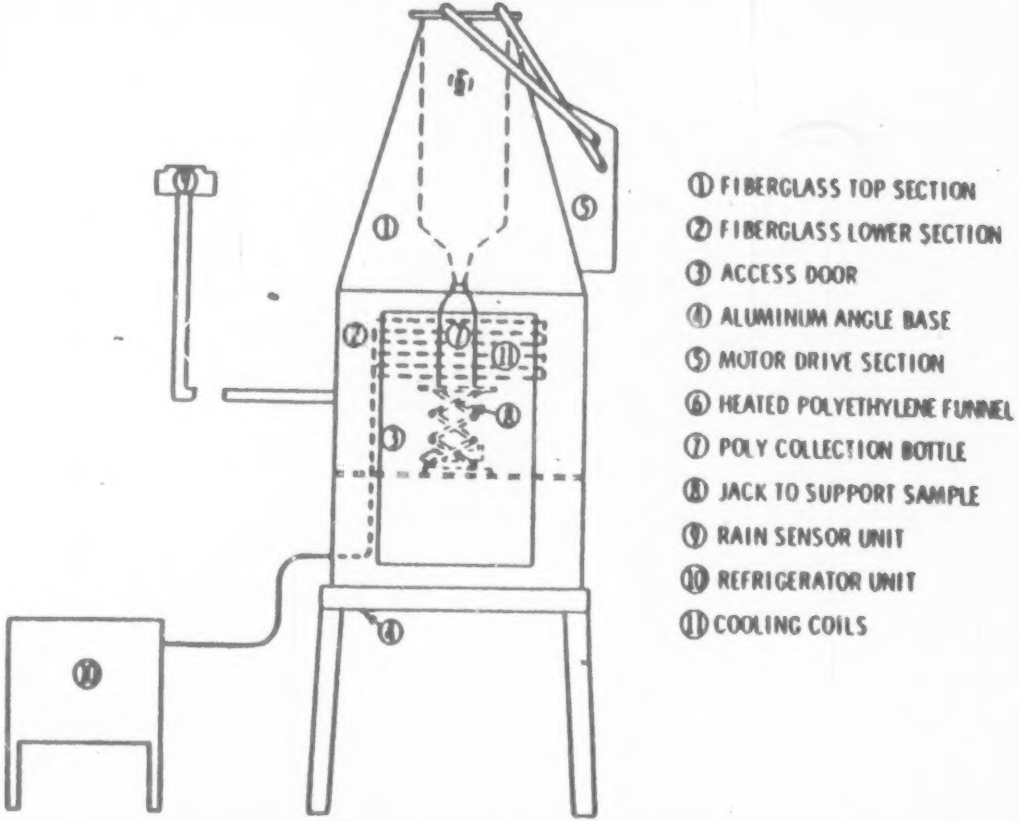

① FIBERGLASS TOP SECTION
② FIBERGLASS LOWER SECTION
③ ACCESS DOOR
④ ALUMINUM ANGLE BASE
⑤ MOTOR DRIVE SECTION
⑥ HEATED POLYETHYLENE FUNNEL
⑦ POLY COLLECTION BOTTLE
⑧ JACK TO SUPPORT SAMPLE
⑨ RAIN SENSOR UNIT
⑩ REFRIGERATOR UNIT
⑪ COOLING COILS

Figure 3. The PNL-designed precipitation collector used by the MAP3S precipitation network. (MacCracken,1979)

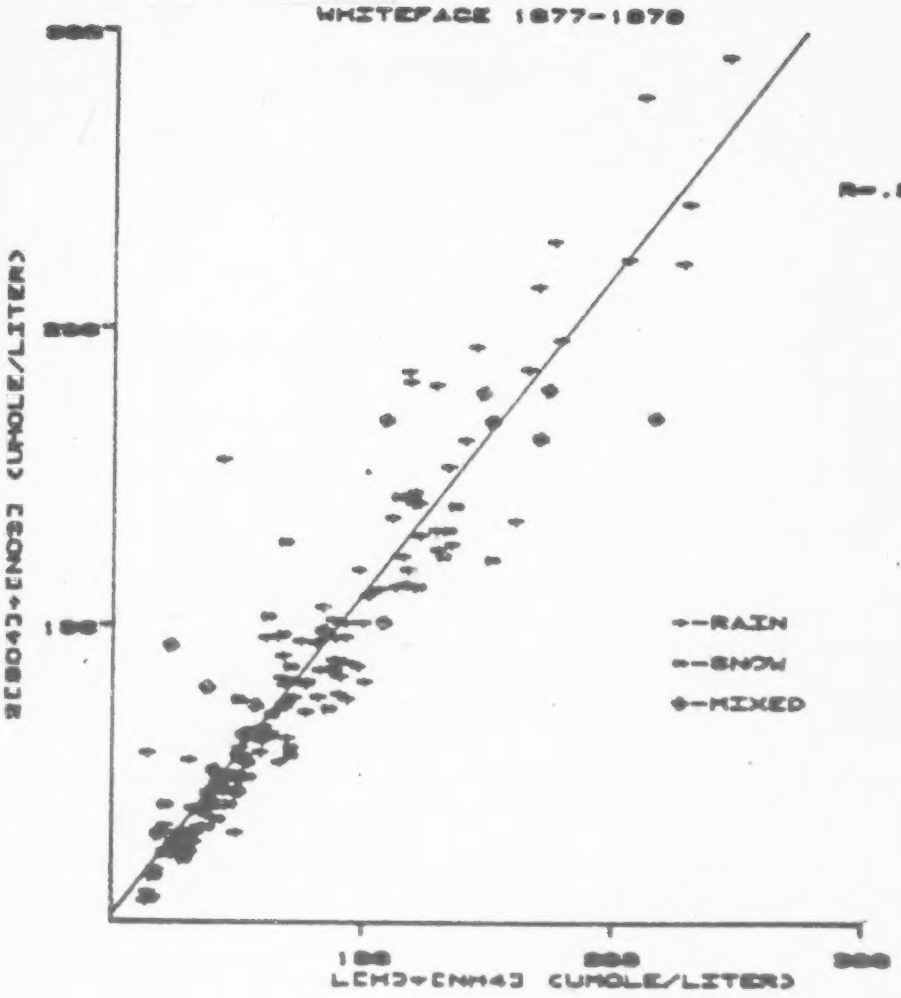


Figure 4. Hydrogen + Ammonium vs. 2(Sulfate) + Nitrate for Whiteface, 1977-1979.

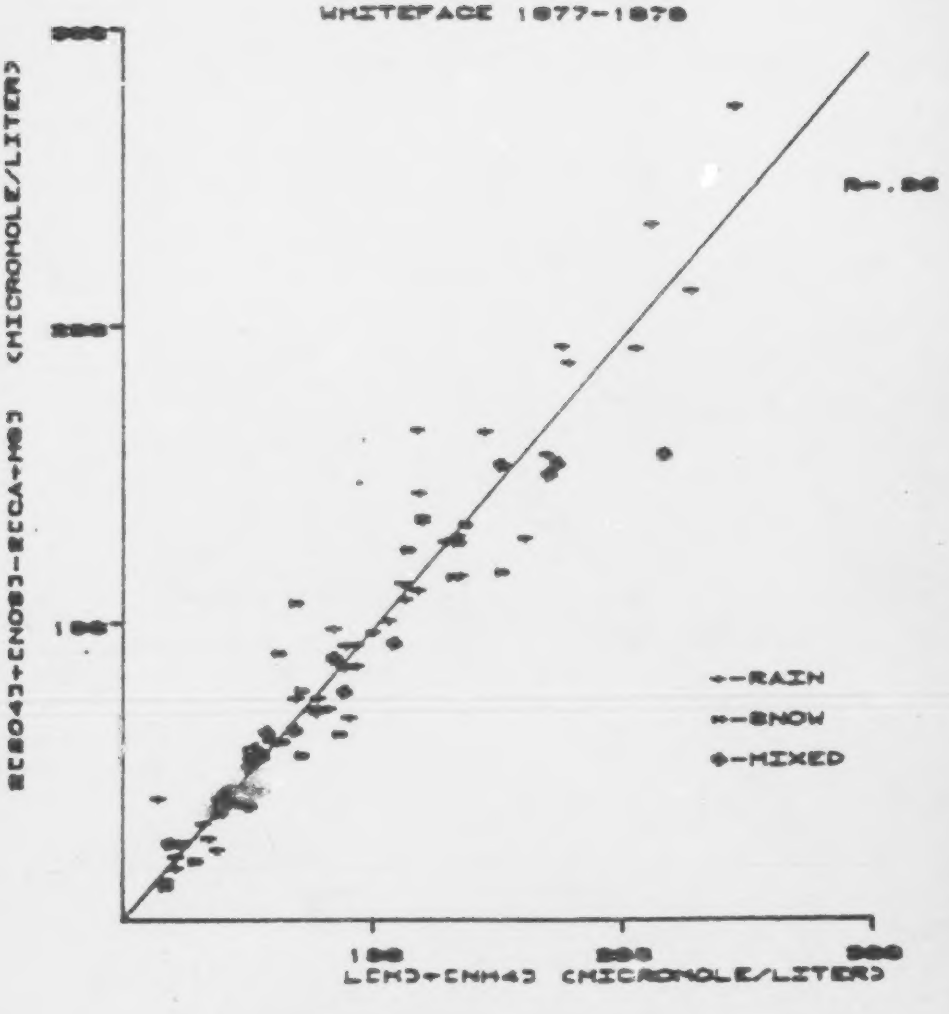


Figure 4a. Hydrogen + Ammonium vs. 2(Sulfate) + Nitrate - 2(Soil Components) for Whiteface, 1977-1979.

This procedure can also be used to determine the degree of dependency of the pH, or H^+, upon the other three major constituents. The concentration of H^+ in precipitation is bound primarily by $SO_4^=$, to a lesser extent NO_3^-, and finally NH_4^+. This conclusion applies to all types of precipitation for all three analyses and for the northeastern United States.

The results from Whiteface Mountain are identical to those obtained from Ithaca or from any other station in the MAP3S network. This does not mean that ammonia and hydrogen ions are the only positive ions and it does not mean that sulfate and nitrate are the only negative ions. There are, depending on the station location, a host of other anions and cations present. But eventually it is the correlation between ammonia and hydrogen ion versus sulfate and nitrate ions that best classifies the precipitation in the northeastern United States. If one goes west of 85° longitude, the picture may be totally different. There may be almost no free hydrogen ions found in areas where the soil is alkaline. This has been demonstrated very clearly in some of the NADP measurements.

Knowing that the ionic balance between hydrogen ion, ammonia, sulfate and nitrate is a good, although not a complete, indicator for acid precipitation, we now turn to the problem of the ion "deposition" versus back trajectory analysis.

I am now showing values primarily from the Whiteface Mountain station. This is an ASRC station in the center of the Adirondacks designated as the Rural Precipitation Chemistry Center. The 200 or so lakes that cover 10,000 acres and are allegedly without fishlife are mostly located in the high peak area (2,000 feet and above) in the vicinity of Whiteface Mountain.

The other results that I am discussing here will be from the Illinois site. One can, therefore, see data from the western end of a major emission region and the eastern end with the Tennessee and Ohio Valleys located in between. This will enable us to investigate the problem of whether or not and to what degree the Tennessee Valley/Ohio Valley contribute to the wet ion deposition of pristine areas such as Whiteface Mountain in the Adirondacks.

In general, I am reporting deposition values here. Obviously, there are two parameters: one is "concentration" of pollutant-related ions in precipitation; the other is "deposition" of pollutant-related ions. Effects researchers like to see deposition numbers because it is the amount of precipitation that brings down the pollutant material that eventually will lead to effects. One could analyze every event in regard to the air mass origin. This can be accomplished by calculating back trajectories for every event for the past two-day travel of air parcels prior to their arrival at Whiteface Mountain and Illinois. In that sense, one can then see whether or not Canadian air (air that has passed during the past two days over Canada) shows a different ion deposition than air that has spent the past two days in the Midwest/Ohio Valley.

To this extent, the Air Resources Laboratories' Atmospheric Transport and Dispersion Model (ARL-ATAD) was used to develop a trajectory climatology in conjunction with the precipitation chemistry at the Whiteface Mountain and Illinois sites. Trajectories were calculated for all of 1978 and 1979 and weighted by precipitation amounts during every six-hour period to determine a dominant direction or origin of air mass for each MAP3S precipitation event. Each event was then classified in one of twelve sectors covering 30° each. Only the final two days (48 hours) of approach trajectory end points were considered. This allowed differentiation between so-called "Ohio Valley/Midwest" and "Canadian/Great Lakes" air masses. The so-classified wet ion deposition is plotted as a function of trajectory sector in Figures 5 through 7.

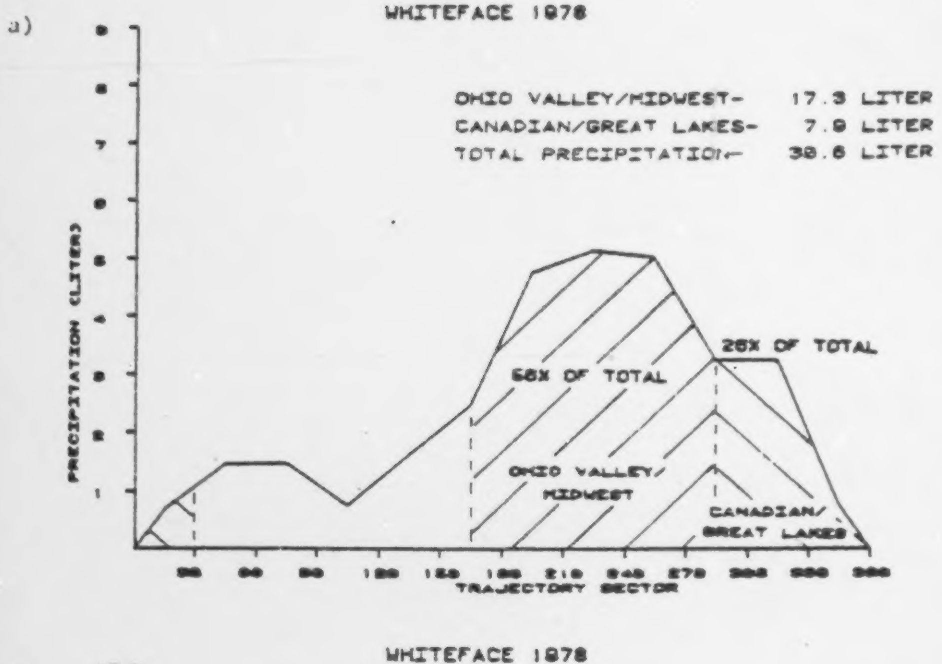


Figure 5. a) Precipitation volume, and b) Free hydrogen ion total wet deposition per 30° trajectory for Whiteface, 1978.

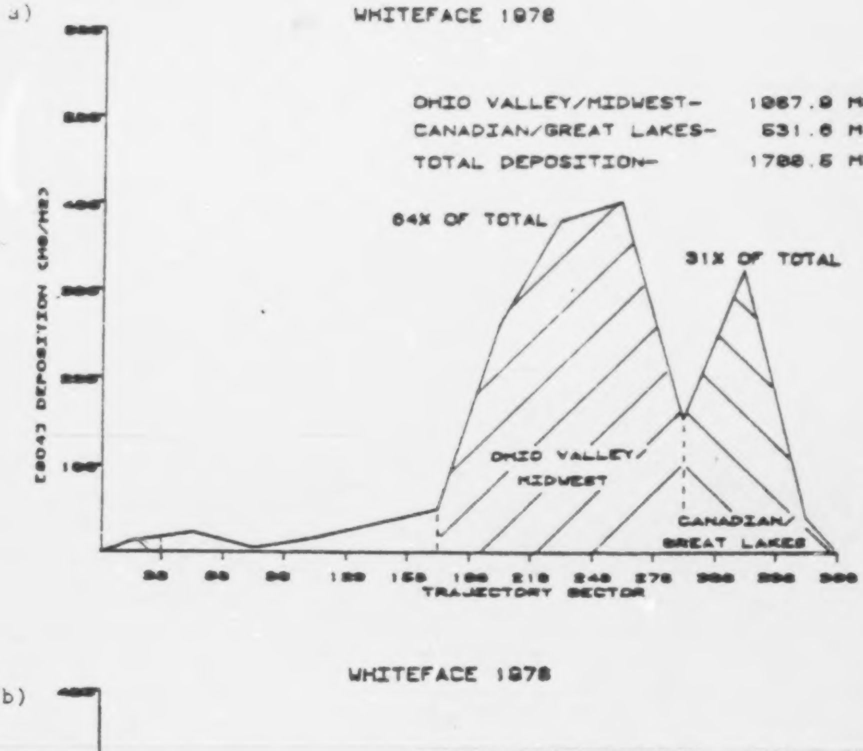


Figure 6. a) Sulfate, and b) Nitrate total wet deposition per 30° trajectory sector for Whiteface, 1978.

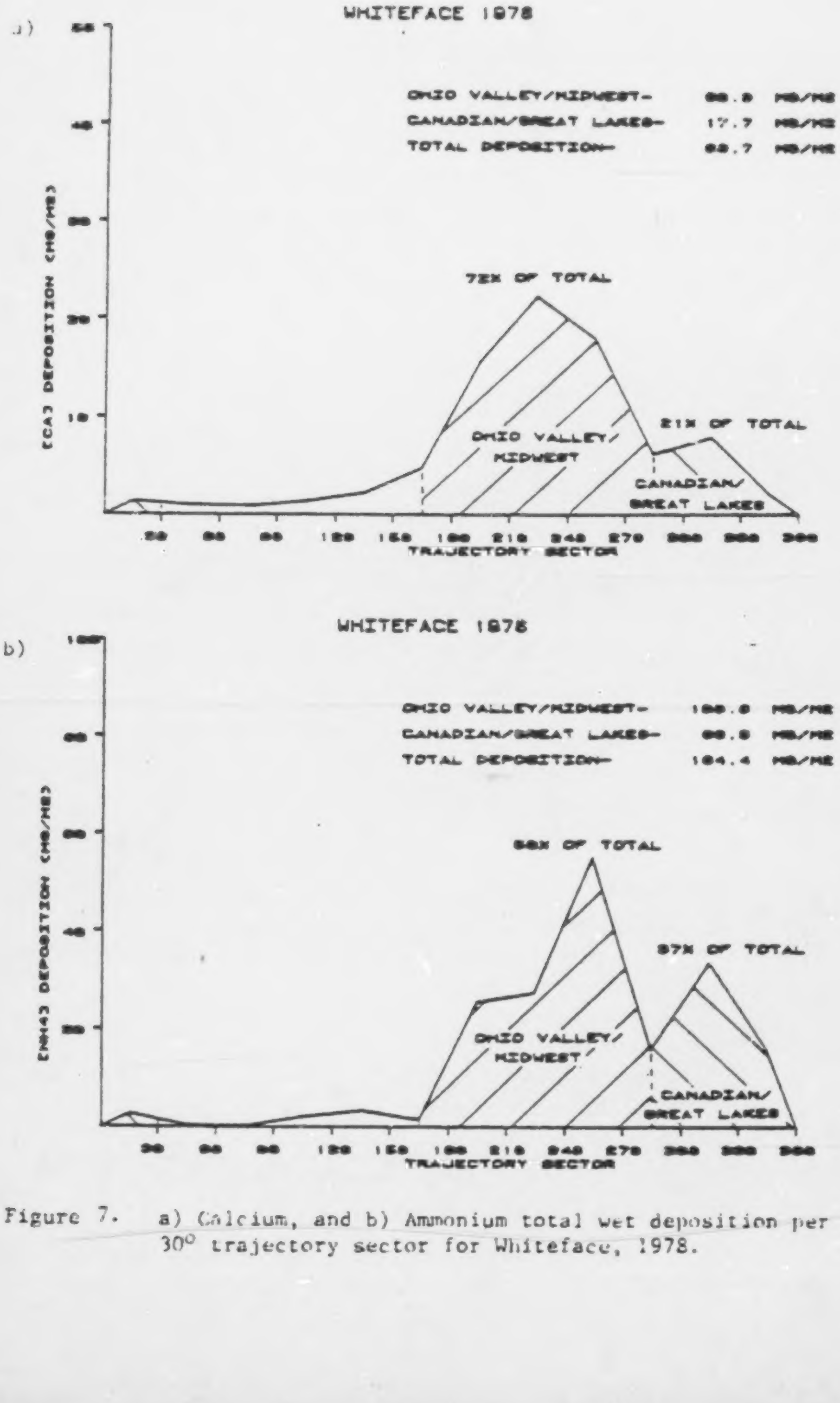


Figure 7. a) Calcium, and b) Ammonium total wet deposition per 30° trajectory sector for Whiteface, 1978.

The Ohio Valley/Midwest events were defined as those having their origin in the sector 165° through 285°, while the Canadian/Great Lakes events were designated by the sector 285°-30°. The wet deposition directional patterns for all ions were found to closely follow the precipitation variability in every case. The wet deposition cumulative total of the Ohio Valley/Midwest sector was found to account for approximately 50-70% of the total wet deposition that could be classified into the 48-hour approach trajectories. Wet deposition from the Canadian/Great Lakes sector resulted largely from winter coastal storms in the form of snow or mixed precipitation. Even though ionic concentrations were generally lower for these events, the large values of precipitation sample volume resulted in almost 30% of the total wet deposition at Whiteface Mountain.

The same analysis procedure (ARL-ATAD model) was applied to the MAP3S precipitation chemistry for the Illinois site during 1978. Since large pollutant sources for SO_2, NO_x, etc., lie to the east or southeast of the Illinois station, one might expect to see a significant difference in the deposition pattern of pollution-related ions observed at Whiteface Mountain during the same year. The cumulcative wet deposition total at Illinois for these events is plotted in Figures 8 and 9 revealing a very interesting picture. Approximately 70% of the total precipitation for Illinois was found to be associated with the southwest approach sector. This is consistent with synoptic considerations whereby southwesterly flow normally precedes an approaching cyclone system and subsequent deposition events. The remainder of the precipitation was found to be essentially equally distributed over the various sectors with the exception of the 0-30° segment.

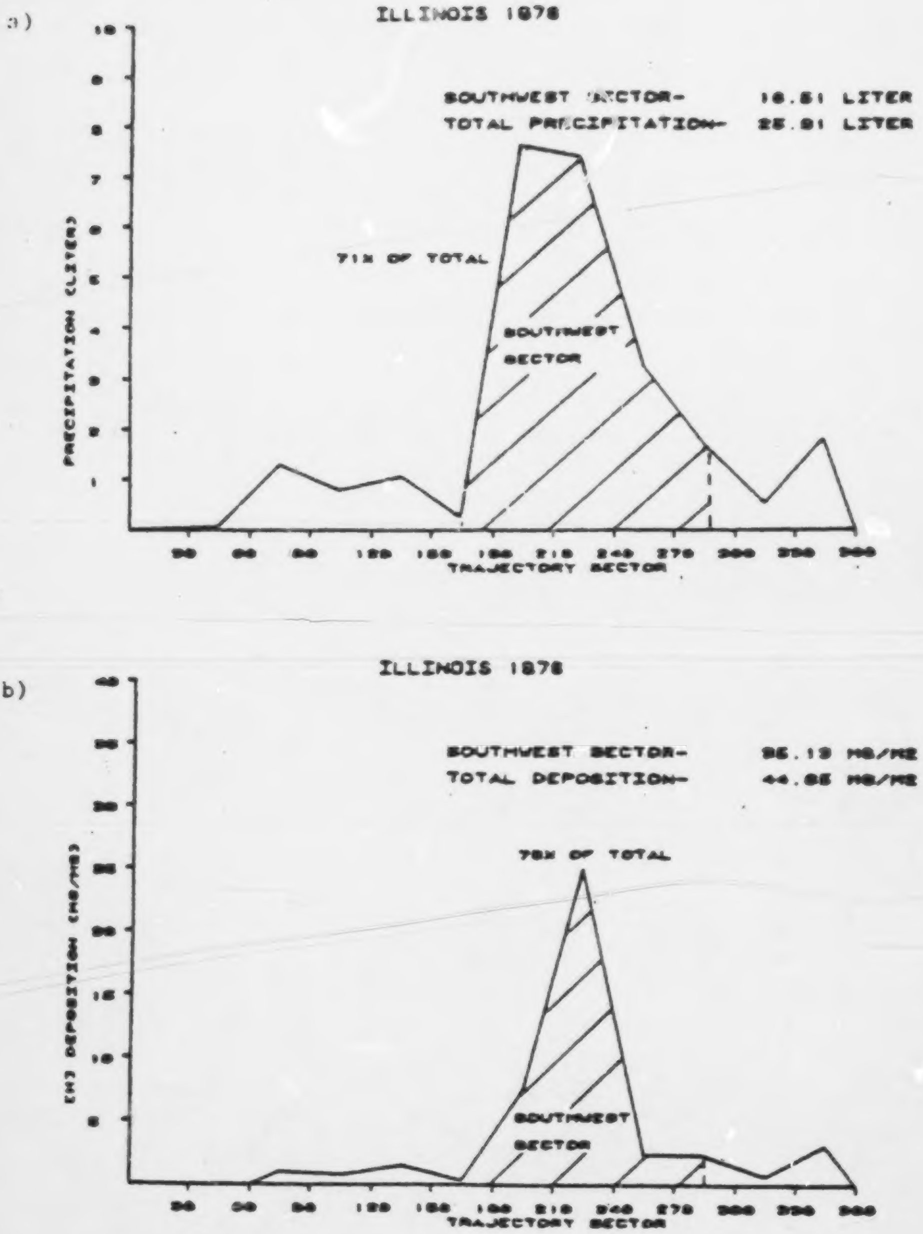
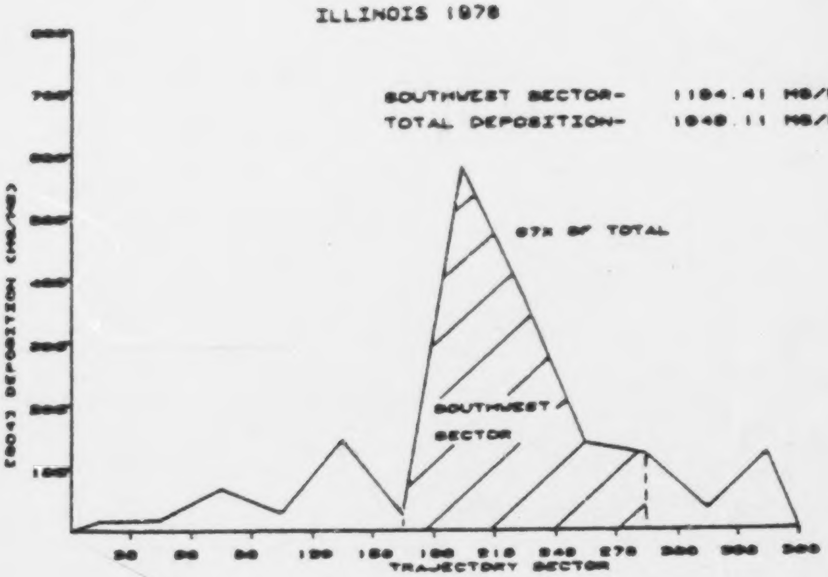


Figure 8. a) Precipitation, and b) Free hydrogen ion deposition per 30° trajectory sector for Illinois, 1978.

a)



b)

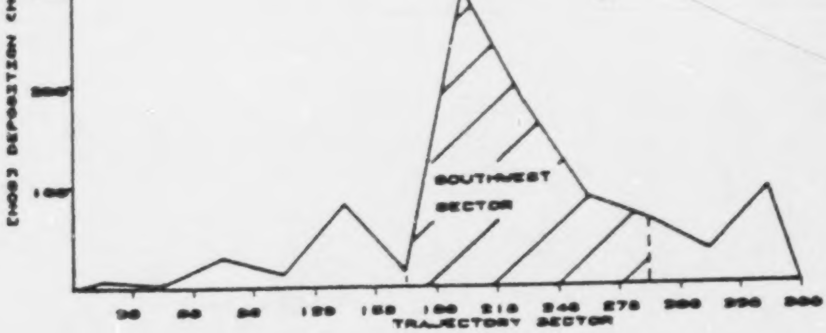


Figure 9. a) Sulfate, and b) Nitrate deposition per 30° trajectory sector for Illinois, 1978.

Air masses approaching the Illinois site from the southwest were found to deliver about 70% of the total annual precipitation resulting in the deposition of approximately 70% of the major ions (Figures 8 and 9). One can again see that wet deposition of pollution-related ions depends primarily on the precipitation amount.

One might expect to see significant differences in precipitation chemistry as air masses from different regions arrive at a receptor site. However, the analysis shows:

Whiteface Mountain (1978)

Midwest/Ohio Valley (160°-280° sector)	56% of the annual precipitation delivering
	62% of the annual $[H^+]$ deposition
	64% of the annual $[SO_4^=]$ deposition, and
	65% of the annual $[NO_3^-]$ deposition
Canadian/Great Lakes (280°-30° sector)	26% of the annual precipitation delivering:
	31% of the annual $[H^+]$ deposition
	31% of the annual $[SO_4^=]$ deposition, and
	28% of the annual $[NO_3^-]$ deposition

Illinois (1978)

(160°-280° sector)	71% of the annual precipitation delivering:
	78% of the annual $[H^+]$ deposition
	67% of the annual $[SO_4^=]$ deposition, and
	64% of the annual $[NO_3^-]$ deposition

It is quite apparent that the precipitation volume, more than any other single factor, determines the amount of deposition for the three pollution-related ions, $[H^+]$, $[SO_4^=]$ and $[NO_3^-]$. The deposition of ions from the Midwest/Ohio Valley air and Great Lakes/Canadian air does not reflect the very significant differences in emissions that are located in these two regions. The Illinois results further substantiate the above conclusion. There seems to exist no simple, straightforward relationship between emission source(s) for acid precipitation precursor gas(es) and receptors of "acid rain," i.e., $[H^+]$, $[SO_4^=]$ and $[NO_3^-]$ ions. The chemical transformation pathway(s) seem to be complex and insensitive to a 48-hour back trajectory analysis presented here and based upon available meteorological and chemical information.

The concept of a "superbowl" (synoptic scale air shed) would explain to some extent the uniformity in directional variability of annual wet ion deposition in that the final products, i.e., acidic material is being rather evenly deposited over a very large region.

The actual wet deposition values for 1979 for sulfate and nitrate ions in milligrams per meter squared are listed for a few MAP3S stations in Figure 10. For example, we can see that 1908 milligrams of sulfate ions per square meter were deposited at Whiteface Mountain in 1979, versus 2,430 in Ithaca; 3,100 in Penn State; 2,400 in Oxford, Ohio; and 1,000 in Illinois. One is inclined immediately to jump to the conclusion that there exists a tremendous deposition gradient from west to east--1,000 mg/m^2 deposited in a year in Illinois; 2,000 in Ohio; 3,000 in Pennsylvania; over 2,000 in New York State (Ithaca); and 1,900 in the Adirondack Mountains.

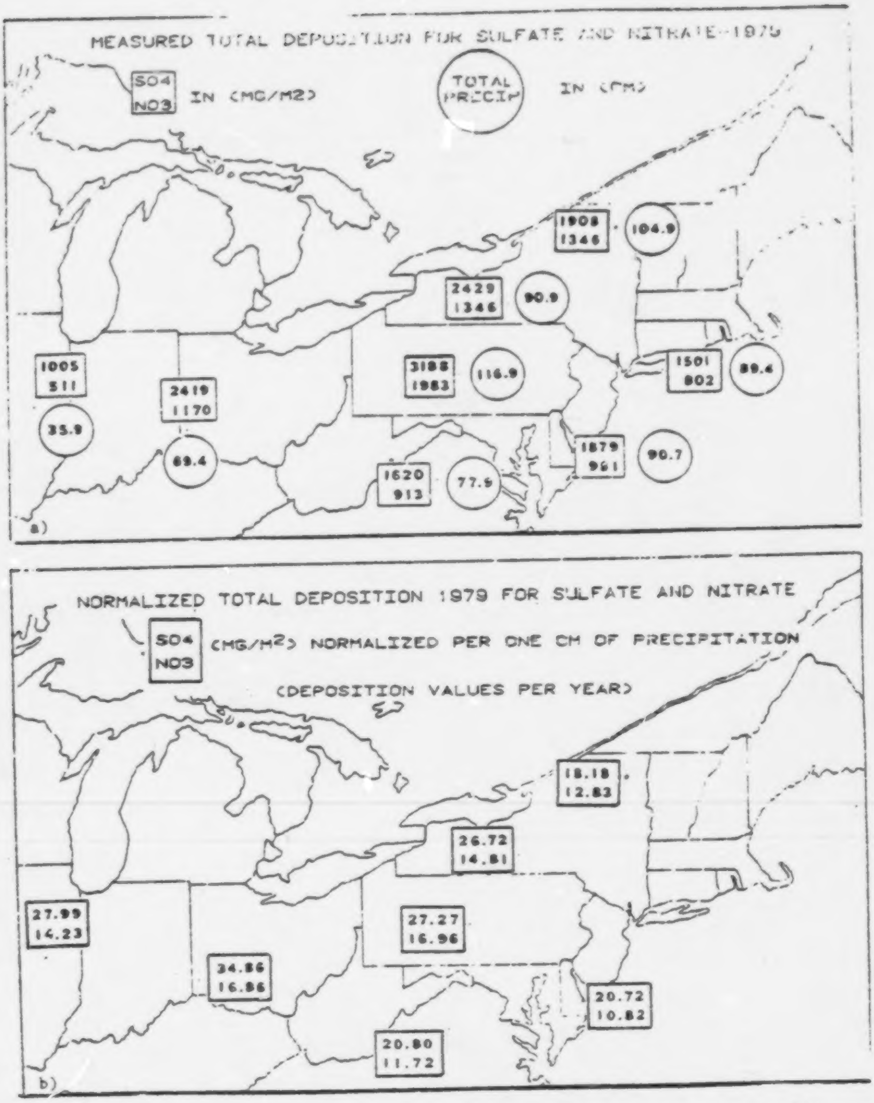

MEASURED TOTAL DEPOSITION FOR SULFATE AND NITRATE-1979
SO4
NO3
IN (MG/M2)
TOTAL
PRECIP
IN (CM)
1908
1346
104.9
2429
1346
90.9
1005
511
2419
1170
3188
1983
116.9
1501
802
89.4
35.9
69.4
1879
961
90.7
1620
913
77.5
a)
NORMALIZED TOTAL DEPOSITION 1979 FOR SULFATE AND NITRATE
SO4
NO3
(MG/M2) NORMALIZED PER ONE CM OF PRECIPITATION
(DEPOSITION VALUES PER YEAR)
18.18
12.83
26.72
14.81
27.99
14.23
27.27
16.96
34.86
16.86
20.72
10.82
20.80
11.72
b)

Figure 10. a) Measured, and b) Normalized sulfate and nitrate deposition, 1979

One can make the same (I might now add wrong and premature) conclusions in regard to a possible west-east deposition gradient by looking at nitrate ion deposition: 500 mg/m^2 per year at Illinois; 1,100 for Oxford; 1,900 for Penn State; 1,300 for Ithaca; and 1,300 for Whiteface Mountain. Obviously one important parameter has not been taken into account, namely the total annual precipiation amount. For example, Whiteface Mountain received 104 centimeters of precipitation in 1979, versus Illinois which received only 35.9 centimeters. Obviously, Whiteface Mountain received three times more precipitation than Illinois and should, therefore, also record a higher value for wet ion deposition. To circumvent the problem arising from different precipitation amounts for different sites, one has to normalize or standardize the wet deposition by the annual precipitation amount to obtain the normalized deposition of sulfate and nitrate ions per one centimeter of precipitation. We now see a different wet deposition pattern: 28 milligrams of sulfate ions per meter squared per year per centimeter of precipitation in Illinois, 34 at Oxford, 27 at Penn State, 26 at Ithaca and 18 at Whiteface Mountain (see Figure 10). There is no significant wet deposition gradient discernible anymore. This is a very important conclusion that further supports the concept of a "superbowl" for the annual wet deposition of pollution-related ions.

As mentioned earlier, several North American precipitation networks operate independently. It is, therefore, possible to correlate their results through proper analysis techniques. Two programs offering regional coverage, accessible data and reliable quality control are MAP3S and NADP. Even though MAP3S is event-oriented, while NADP collects weekly samples, their integrated ion deposition measurements are compatible when compared over time scales in excess of one year. Figures 11 and 12 show the location of the MAP3S

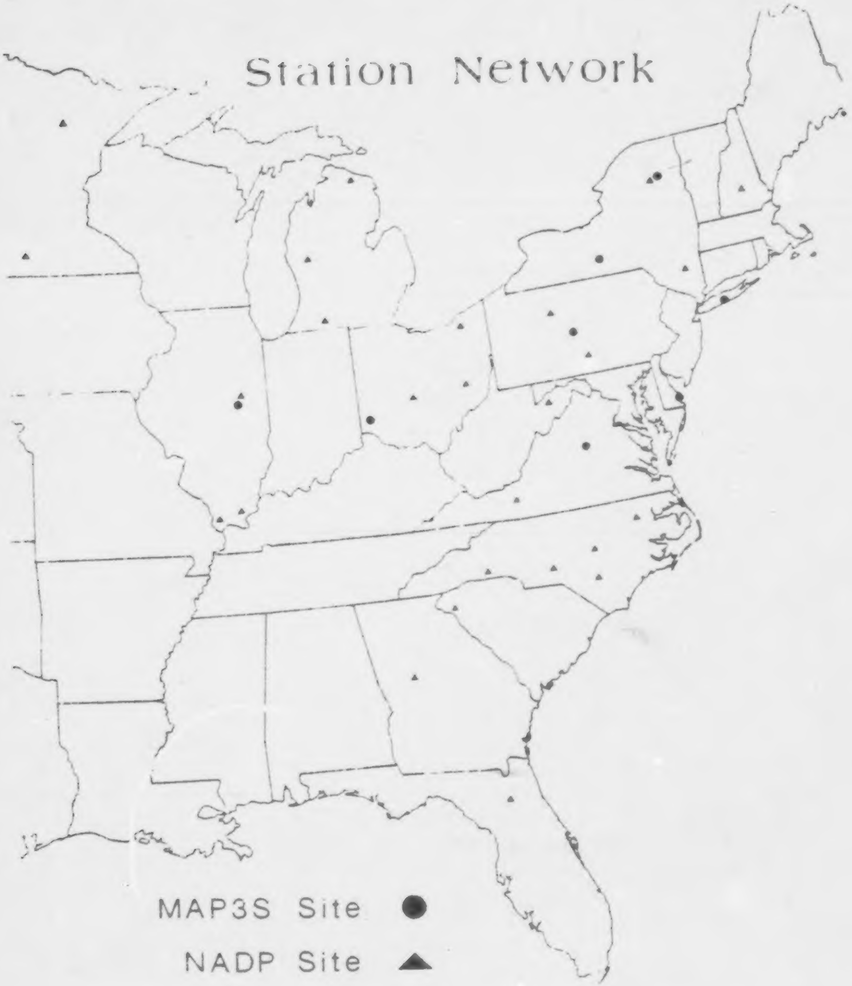

Station Network
MAP3S Site ●
NADP Site ▲

Fig. 11. MAP3S and NADP station network used for 1979 spatial deposition analysis

Figure 12

NADP Stations Used in 1979 Inter-Comparison Study

State	Site Name	Latitude	Longitude
Florida	Bradford Forest	29.97	82.20
Georgia	Georgia Station	33.18	84.40
Illinois	Bondville	40.05	88.37
Illinois	SIU	37.70	89.27
Illinois	Dixon Springs Ag. Ctr.	37.43	88.67
Michigan	U. Mich. Biological Sta.	45.57	84.68
Michigan	Kellogg Biological Sta.	42.48	85.38
Michigan	Wellston	44.22	85.85
Minnesota	Marcell Exp. Forest	47.50	93.47
Minnesota	Lamberton	44.25	95.32
Nebraska	Mead	41.09	96.50
New Hampshire	Hubbard Brook	43.95	71.70
New York	Huntington Wildlife	44.00	74.22
New York	Stilwell Lake-West Point	41.35	74.03
North Carolina	Lewiston	36.13	77.17
North Carolina	Coweeta	35.02	83.45
North Carolina	Piedmont Research Sta.	35.67	80.57
North Carolina	Clinton Crops Res. Sta.	35.01	78.28
North Carolina	Finley	35.73	78.68
Ohio	Delaware	40.28	83.06
Ohio	Caldwall	39.78	81.52
Ohio	Wooster	40.77	81.93
Pennsylvania	Kane Exp. Forest	41.55	78.77
Pennsylvania	Leading Ridge	40.55	77.93
South Carolina	Clemson	34.67	82.83
Virginia	Horton's Station	37.18	80.42
West Virgnina	Parsons	39.10	79.65

and NADP sites of the eastern United States. Total wet deposition was normalized per centimeter of precipitation as outlined earlier. To insure complete objectivity, spatial distributions of normalized wet deposition were analyzed using the Synagraphic Mapping System developed by the Laboratory for Computer Graphics and Spatial Analysis, Harvard University.

The resulting wet ion deposition patterns, normalized for one centimeter of precipitation, are shown in Figures 13-16. These objective analyses for the 1979 wet deposition of sulfate ($SO_4^=$), nitrate (NO_3^-), hydrogen (H^+) and ammonium ions again offer a surprising conclusion: there is no significant west-east gradient for the pollution-related ions $SO_4^=$ and NO_3^-. There exists a rather uniform gradient in almost every direction from major emission areas that are located in the Midwest/Ohio Valley. Furthermore, no maxima can be observed in the northeastern United States in these wet deposition values that would be indicative of increased wet deposition downwind of major emission areas. However, the effect of the Appalachian Mountains seems to be readily apparent, as evidenced by the strong wet deposition gradients in the northwest-southeast direction.

A slightly more complex picture emerges for the hydrogen ion deposition (H^+) in Figure 15. The free hydrogen ion deposition results from the contribution of various constituents including sulfuric acid, nitric acid, ammonium and soil-related components such as calcium and magnesium. Therefore, its spatial distribution can be expected to be more complex than the normalized wet deposition pattern of $SO_4^=$ or NO_3^- alone. This is indeed verified in Figure 16. Localized maxima in H^+ wet deposition are evident and a strong gradient emerges to the west of 85° longitude. One can speculate that soil-related material scavenged by precipitation might be responsible for the apparent change in free hydrogen ion deposition. This view is strongly supported by the normalized wet deposition emerging for the ammonium

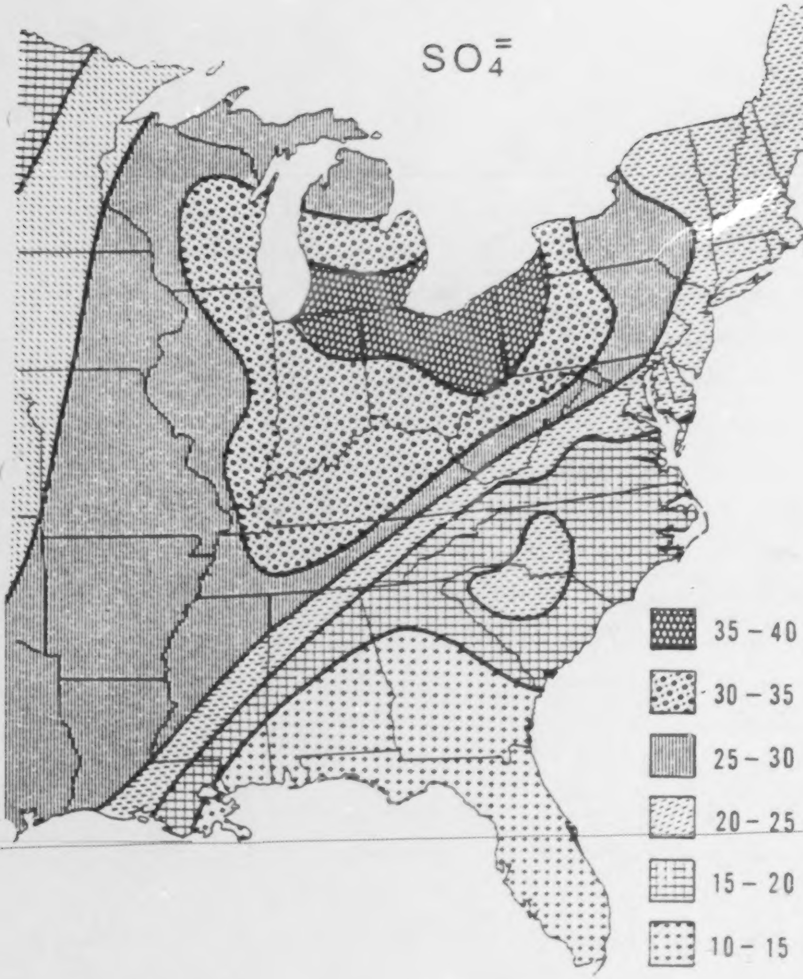

$SO_4^=$
35 – 40
30 – 35
25 – 30
20 – 25
15 – 20
10 – 15

Fig. 13. $SO_4^=$ deposition (mg/m^2) normalized per cm of precipitation for 1979

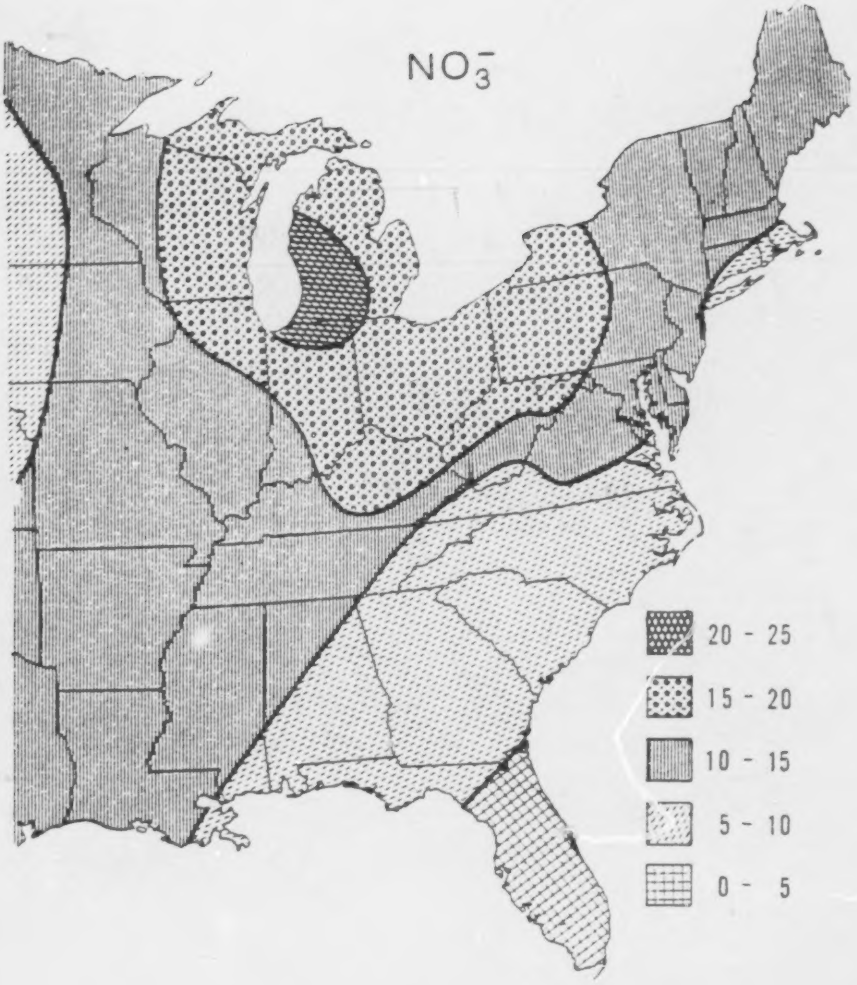

NO_3^-
20 - 25
15 - 20
10 - 15
5 - 10
0 - 5

Fig. 14. NO_3^- deposition (mg/m^2) normalized per cm of precipitation for 1979

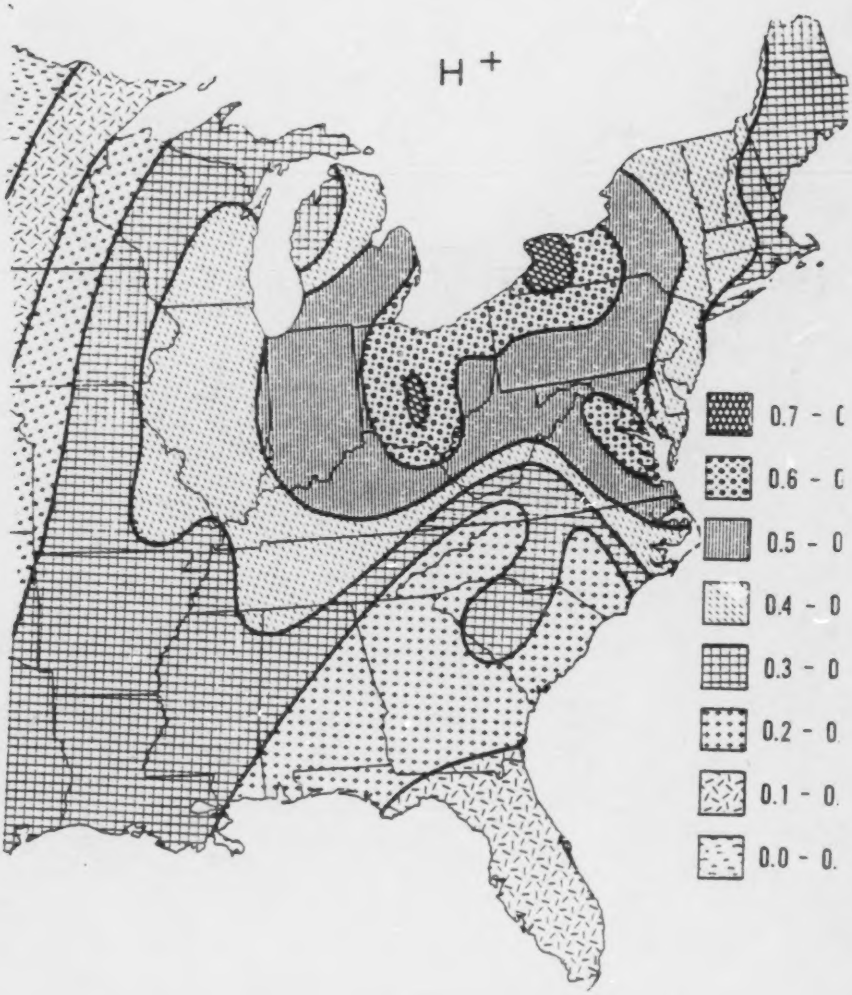

H^+
0.7 - 0
0.6 - 0
0.5 - 0
0.4 - 0
0.3 - 0
0.2 - 0
0.1 - 0.
0.0 - 0.

Fig. 15. H^+ deposition (mg/m^2) normalized per cm of precipitation for 1979.

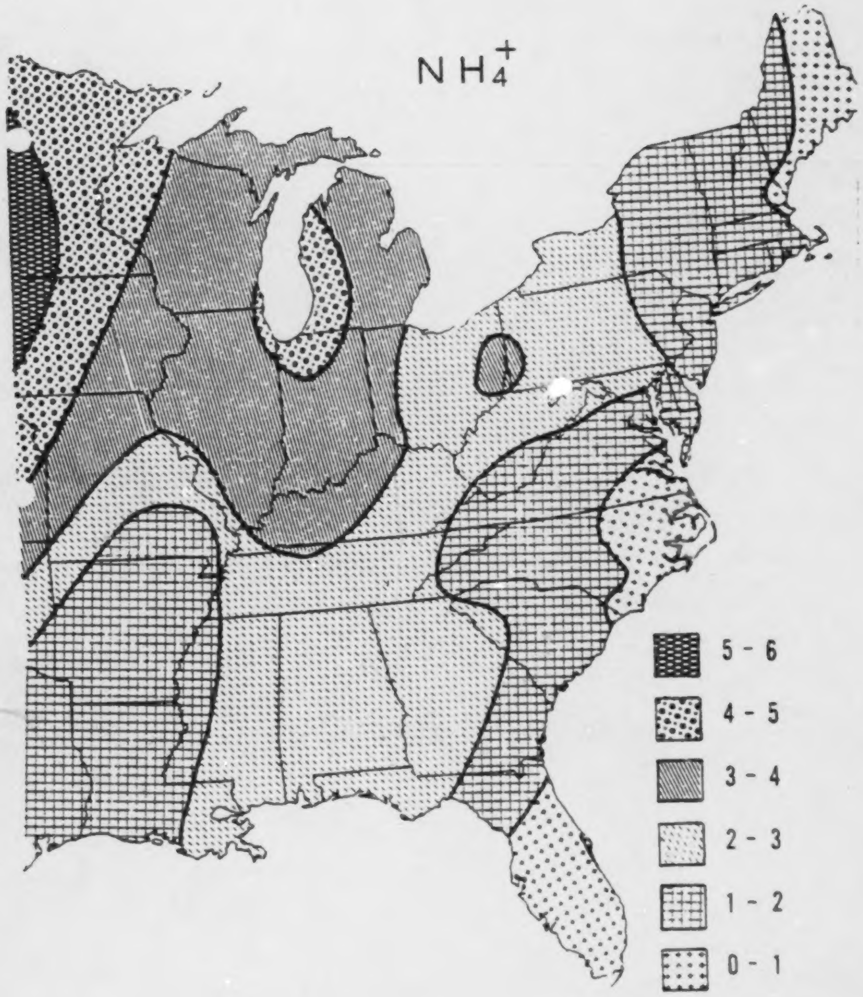

NH_4^+
5 - 6
4 - 5
3 - 4
2 - 3
1 - 2
0 - 1

Fig. 16. NH_4^+ deposition (mg/m^2) normalized per cm of precipitation for 1979 ion (see Figure 16). The normalized NH_4^+ deposition is largely a function of natural sources: increased NH_4^+ ion deposition to the west of 85° longitude correlates well with the decrease in free hydrogen ion deposition, since NH_4^+ acts as a "neutralizing agent".

Again, the concept of a "superbowl" can be used in the absence of a source-receptor relationship (emission-wet deposition relationship) to explain the relatively uniform west-east wet deposition distribution pattern for sulfate and nitrate ions.

I hope that I was able to demonstrate to you the complexity of acid precipitation. Indeed, we have a rather good knowledge of the emission of sulfur and nitrogen compounds. At the same time, we now seem to have good information on the wet deposition of nitrate and sulfate ions. But establishing a source-receptor relationship is very difficult. Classical meteorology, coupled with classical knowledge of air pollution and air chemistry, cannot identify the mechanisms and transformations at work. We are unable to understand the complex chemistry involved in transforming SO_2 and NO_x into sulfate and nitrates. It is slowly being revealed that the processes are more complex than anything we have dealt with in air pollution so far. It involves the chemical conversion of gases such as SO_2, NO_x, hydrocarbons, etc., into material such as nitric acid and sulfuric acid that are picked up by particles, cloud droplets and hydrometeors. The rate controlling step does not necessarily seem to be the absolute concentration of the precursor gases SO_2 and NO_x, but seems to be either meteorology, available sunshine, the ratio of SO_2/NO_x or other parameters, or a combination of the above. With our limited knowledge today, the emissions seem to be essentially decoupled from the depositions. We simply need to know more.

The general motherhood statement, "What goes up must come down", certainly holds true. If this is all you are interested in, then we can stop right there and need no further research efforts. But if we want to know how much we have to reduce emissions in one part of the country to achieve improvements in wet deposition of pollution-related ions in another part of the country, then we will have to be more patient.

BEFORE THE
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

In the matter of:

Petitions of the State of New York and the Commonwealth of Pennsylvania under Section 126 of the Clean Air Act for Interstate Pollution Abatement

Docket No. A-81-09

STATEMENT OF VOLKER A. MOHNEN, Ph.D.,

Director, Atmospheric Sciences Research Center,
State University of New York at Albany

June 19, 1981

My name is Volker A. Mohnen. I hold a Ph.D. degree in physics, with a minor in meteorology and astrophysics, from the University of Munich. I am currently the Director of the Atmospheric Sciences Research Center and Research Professor in the Department of Atmospheric Sciences at the State University of New York at Albany and am actively involved in research in the fields of air pollution, aerosol physics, and meteorology. I am an author of more than 100 publications dealing with those subjects. My curriculum vitae is attached hereto.

I am presenting this statement, at the request of Peabody Coal Company, on the petitions filed by New York and Pennsylvania under § 126 of the Clean Air Act, which are the subject of this hearing. As stated in EPA's

Federal Register notice of May 1, 1981 (46 Fed. Reg. 24603), the inquiry in this hearing is limited to whether emissions from the Midwestern power and industrial plants identified by New York and Pennsylvania prevent attainment or maintenance of the national ambient air quality standards, or interfere with measures for prevention of significant deterioration (PSD), in those States. In accordance with that notice, the specific question which I will address is whether SO_2 emissions from the identified plants result, through transformation into sulfates and long-range transport, in sulfate levels in New York or Pennsylvania which prevent attainment or maintenance of the national ambient standards for total suspended particulates (TSP), or interfere with PSD measures relating to TSP, in either of those Northeastern States. In addressing this question, I will limit my discussion to the problem of long-range transport (LRT) -- i.e., the impact on New York or Pennsylvania of sources located more than about 100 kilometers from their borders.

As I will show, use of air quality modeling to establish source-receptor relationships over such long distances is fraught with uncertainties. At the present time, no model exists that is capable of establishing, with sufficient accuracy for regulatory use, such source-receptor relationships between SO_2 emissions and ambient sulfate or TSP levels in the LRT range. Indeed, EPA itself has recently reiterated that its approved models are not sufficiently reliable for regulatory use beyond even 50 kilometers from the source in question. 46 Fed. Reg. 8488 (Jan. 27, 1981).

On the basis of the data currently available, there is no reliable evidence that SO_2 emissions from the sources identified by New York and

Pennsylvania in this proceeding in the range of long-distance transport are significantly related to sulfate levels in New York or Pennsylvania, much less cause violations of the national ambient TSP standards or interference with the PSD plans for TSP in those States. It follows that there is no valid evidence that even a substantial reduction in SO_2 emissions from those sources would have any measurable impact in reducing sulfate levels, or TSP violations, in New York or Pennsylvania.

I. STUDIES ATTEMPTING TO DETERMINE THE CAUSE OF ELEVATED SULFATE LEVELS IN THE NORTHEAST

According to the petitions filed by New York and Pennsylvania in this proceeding, SO_2 emissions from the listed Midwestern sources in the LRT range affect the ambient standards and PSD provisions for TSP in those States through transformation into, and long-distance transport of, sulfates. Accordingly, I will begin by discussing the studies that have investigated the causes of elevated sulfate levels in those States and have attempted to determine the relationship between such levels and SO_2 emissions in the Midwest.

A. Early Studies Using Insufficiently Refined Techniques

Many of the studies cited in New York's and Pennsylvania's petitions to support their contention that elevated sulfate levels in those States are related to high SO_2 emissions from Midwestern sources are relatively early efforts to investigate the potential origin of high ambient sulfate concentrations at monitoring sites in the Northeastern States. When those elevated sulfate concentrations could not be fully explained by local sources, the investigators in these studies attempted, largely by analysis of wind field data, to relate them to SO_2 emissions from upwind sources allegedly located in the Midwest. Reliance on these studies is particularly apparent in New York's petitions, which place primary reliance on such early studies as those by Lioy *et al.* (1977), Galvin *et al.* (1978), Coffey *et al.* (1979), Kolak *et al.* (1979), and Niemann and Mahan (1978) (an interim report in the Ohio River Basin Energy Study (ORBES)).*/

These studies did not attempt to identify particular sources of SO_2 responsible for the elevated sulfate levels, and certainly did not specifically implicate SO_2 emissions from the sources named by New York and Pennsylvania in this proceeding. Moreover, these studies used relatively crude and simple techniques which subsequent studies have shown to be insufficiently refined to reliably identify the regional origins and causes of the elevated sulfate levels. As I will show, these newer studies, which used more sophisticated techniques, have supplanted the earlier investigations by showing that the identification of the cause of ambient sulfate levels is more complex and involves many meteorological and other factors that are not well understood and that were not adequately taken into account in the earlier studies.

Before turning to these newer studies, I will touch briefly on the above-mentioned studies relied on by New York (and, in part, by

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*/ Pennsylvania's petition relies exclusively, as regards LRT of sulfates, on various ORBES reports, including the interim report by Niemann and Mahan (1978). As to the more recent ORBES reports presenting the results of LRT modeling, I will demonstrate below in section III that at present LRT models are not sufficiently reliable to be used for regulatory purposes to establish source-receptor relationships.

Pennsylvania). This discussion is not intended to be a full and detailed critique of the limitations and shortcomings of these studies. I simply wish to note their findings as background for my later discussion of the subsequent investigations.

Lioy et al. (1977) observed that high levels of sulfates occurred simultaneously at rural sites in New York and New Jersey in July and August 1975 "during periods of anti-cyclonic stagnation and/or were associated with the return flow of warm, moist tropical air on a west-southwesterly to southerly flow" (p. 11). The researchers concluded that "[t]he simultaneous appearance of these high levels of sulfates at all sites in the New York-New Jersey region under the influence of the same air mass indicates that the origin of some of the observed sulfates is due to long-range transport" (p. 11). This study, however, did not attempt to investigate the respective influences of upwind SO_2 emission levels and of the meteorological conditions of stagnation on the elevated sulfate levels observed, and did not imply that high SO_2 emissions were the cause of those sulfate observations.

Galvin et al. (1978) collected suspended particulates at three rural sites and one urban site in New York from July 6 to August 4 of 1976. The researchers computed three-day backward trajectories for the air parcels found at the sampling sites. The trajectories calculated for the days with the lowest concentrations of sulfates indicated that the air sampled had originated in areas to the west and north of New York; trajectories for the days with high concentrations of sulfates indicated that the air parcels had passed through areas southwest of New York. The authors found specifically that elevated sulfate concentrations were measured only in air that had earlier stagnated over an industrialized area of high SO_2 emissions in the Midwest, with the highest concentrations found in air that had passed through the Ohio River Valley.*/ They thus concluded that these sulfate levels were produced by SO_2 emissions from sources in the Midwestern areas in question. I note first that trajectories extending beyond two days carry a significant and increasing margin of error. Moreover, although the authors state that "[s]tagnation of the air did not increase the observed sulfate concentration unless the stagnation occurred in an area of high sulfur dioxide emissions" (p. 583), the analysis was not sufficiently refined to be able to determine whether the primary cause of the elevated sulfate levels was the stagnant conditions (over the area with high SO_2 emissions) or the SO_2 emission levels themselves. (Indeed, a subsequent analysis by Samson, discussed below, implicated the former but not the latter.)

Coffey et al. (1979) continued the work of Galvin et al. by collecting particulates at the same three rural sites and one additional rural site in upstate New York from June 15 to August 15, 1977. They found that the percentage of sulfates in the total aerosol varied over this period, but that on occasion it accounted for half the aerosol mass. They computed three-day backward trajectories for the measured air parcels (for three of the sites) in an attempt to ascertain the origins of the sulfates. This analysis produced these results:

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*/ Although the report thus attempts to implicate specifically the Ohio River Valley, the figures showing example trajectories to support the report's conclusion (Figures 2 and 3) show the air having come, on high-sulfate days, basically from northern Ohio, northwest Pennsylvania, southern Michigan, and northern Indiana. This is not the Ohio River Valley. Indeed, this area contains a number of heavily industrialized cities and not nearly as many coal-fired power plants as the actual Ohio River Valley.

> "Low concentrations of sulfate are found when the air parcel trajectory has not passed over regions of high anthropogenic sulfur dioxide emissions while high concentrations are measured for those trajectories which have passed over areas of high sulfur dioxide emissions. . . . [T]he highest concentrations of sulfates were recorded on brisk southwesterly winds following a stagnation period in the midwest 12 to 36 hours earlier." (P. 2.)

The researchers inferred that high SO_2 emission levels from Midwestern sources were responsible for those instances in which their New York sites experienced high sulfate concentrations, but they also stressed the important influence of the meteorological conditions of stagnation on the elevated sulfate levels. Their analysis, however, was not sufficiently refined to separate these influences, nor did they quantify the "low" and "high" SO_2 emission regions in their attempt to implicate high SO_2 emissions from the Midwest.

With respect to all three of these studies, it is worth noting at this point that Samson, one of the authors of Galvin et al. and Coffey et al., subsequently made a more sophisticated analysis using data that included data from all three of the previous studies (Samson, 1980). As will be discussed in more detail in the next section, that analysis showed that the elevated sulfate levels were positively correlated with the upstream conditions of stagnation, but not with the upstream SO_2 emissions loading.

Kolak et al. (1979) collected and analyzed suspended particulates at five urban sites and one residential/rural site in the Niagara Frontier Air Quality Control Region in upstate New York. They used a computer to resolve each air particulate sample among the various major source categories located within the region. They concluded, among other things, that: (1) most (50-99%) of the sulfur-bearing particulates were sulfates; (2) most (over 95%) of the sulfates were found in the fine fraction (which indicates the result of gas-to-particle conversion); (3) from consideration of wind direction data, it appeared that more than 75% of the sulfate material entered New York from west of Buffalo; (4) the percentage of inhalable particulates (IP) consisting of sulfates remained fairly constant at all six sites throughout the eight months of the study, with a mean overall sulface percentage of approximately 18% of IP; (5) the sulfate percentage of IP cannot be "scaled up" to determine the expected sulfate percentage of TSP, since the factors are frequently different for each particle size fraction; and (6) it appeared that the sulfate component of IP (or TSP) was not significantly affected by local industrial operations or heavy vehicle emissions -- a result that is more consistent with the long-range transport of sulfates into New York on the predominantly southwesterly winds (pp. 2-3 to 2-4, 2-7, 7-3, 7-6). There are a number of flaws in this study.

First, this study's conclusion that over 75% of the sulfates in the Niagara Frontier Region entered New York from west of Buffalo is difficult to verify and appears be based on a misinterpretation of the data. That conclusion apparently derived, at least in part, from a comparison of the annual average sulfate level at the residential/rural site (7.9 $\mu g/m^3$) with the annual average mean of the urban sites (11.7 $\mu g/m^3$) (see p. 7-3). This comparison fails to take account of the "natural" background for sulfate, which is on the order of 1-2 $\mu g/m^3$ on a continental scale, or of local influences on the residential/rural site. Proper calculation shows that the relevant percentage must be less than about 60%.

The Kolak et al. paper also shows discrepancies in the values used to represent the regional background of sulfate. For example, the lowest value observed at any station throughout the study area should be the one most closely representative of regional background (since higher levels will necessarily reflect local influences). Review of the data from Kolak et al. reveals that on several occasions the sulfate values measured in urban Buffalo were lower than the values measured simultaneously at the rural site (see, e.g., p. 7-1).

Another factor that was not adequately explained by Kolak et al. relates to their finding that over 95% of the sulfate was comprised in the fine particle mode (subject to LRT). All other investigators have reported fine fractions up to 80%. It might be speculated that this discrepancy is due to a particle cutoff above 3 μm in the dichotomous sampler of Kolak et al., which would mean that part of the coarse fraction was included in the fine particle measurement.

Finally, and perhaps most importantly for present purposes, the finding of Kolak et al. that the LRT fraction of sulfates, whatever the correct percentage of measured sulfate levels, entered the State from west of Buffalo was based on consideration of wind direction data. The study did not attempt to determine the cause of the imported sulfates or to relate the fraction of sulfates entering the State from the west to high SO_2 emissions in the Midwest. Even if the percentage of sulfates coming from the west and southwest was high, it may simply reflect the fact that the wind blew most often from the west and southwest and that such wind conditions accompanied the meteorological conditions of stagnation, high moisture, high temperature, and sunshine (summer stagnation conditions) that are most conducive to the formation of sulfates, irrespective of SO_2 emission loadings.

Niemann and Mahan (1978), using data from five sampling locations in western Pennsylvania and two in West Virginia, analyzed wind conditions associated with days when the national ambient standards for TSP or the Pennsylvania state standard for sulfates were exceeded or when the measured TSP showed a significant percentage (>10%) of sulfate. They found that these ambient air conditions were most often associated with persistent winds blowing toward Pennsylvania from the southwest, west, or south. These persistent winds, they concluded, could transport pollutants over considerable distances while concentrating the impact within a rather narrow sector downwind in Pennsylvania. This report, too, simply analyzed wind direction data and did not determine the cause of elevated sulfate levels in Pennsylvania or relate them to SO_2 emissions from sources to the southwest, west, or south of the State.

It is important to recognize that, even on their own terms, these studies are of very limited usefulness for purposes of the present inquiry. They do not claim to identify what particular source or sources of SO_2 emissions in the Midwest might be responsible for the elevated sulfate levels observed. Nor do they (except for Niemann and Mahan, 1978) attempt to relate the imported sulfates to particular violations of the national ambient standards or PSD provisions for TSP in New York or Pennsylvania. For these reasons, they do not provide evidence relevant to the question under consideration here -- whether SO_2 emissions from the particular sources identified by New York and Pennsylvania in the LRT range prevent attainment or maintenance of the national ambient standards or PSD provisions for TSP in either of those States.

Moreover, as mentioned above, these studies did not include adequate consideration of the multiple variables that have recently been shown to be of great significance in determining why elevated sulfate levels occur. Such factors appear to include meteorological parameters such as wind speed (stagnation), 24-hour ozone level, midday relative humidity, mixing height, and TSP level less sulfates and nitrates, as well as yet unknown photochemical processes. As I now discuss, recent evidence indicates that these meteorological and photochemical factors have a much greater effect on downwind sulfate concentrations than do upwind SO_2 levels. Without adequate consideration of these factors, efforts to establish source-receptor relationships must be considered unreliable. The mere analysis of the dominant wind direction during ambient sulfate sampling is not a sufficient criterion for "identifying" upwind emissions of the precursor gas, SO_2, as being responsible for the observed sulfate concentrations.

B. Recent Studies Using Sophisticated Statistical or Trajectory Analysis

As early as 1978, studies began to appear (though they are not cited by New York or Pennsylvania) that recognized the profound influence of meteorological and other factors besides SO_2 emissions upon the occurrence of elevated sulfate levels. Hidy et al. (1978) attempted to explain the variability in daily sulfate concentrations for both the Los Angeles area and the New York City area by means of step-wise linear regression. The results -- which are very consistent for both areas (except for Vista, California, a community about 100 miles southeast of Los Angeles) -- indicate that the most important variables are the 24-hour ozone level, the total mass TSP concentration minus the sulfate and nitrate fraction, and the midday relative humidity. The ozone or oxidant levels are an indication of (among other things) water content of the air mass, and TSP mass is an indication of reactions involving particulate matter. The local SO_2 concentration was not found to be a significant factor in explaining the variations in sulfate concentrations.

Other studies focused on the meteorological factors that affect the long-range transport of sulfates. Hidy et al. (1979), in a report on results from the Sulfate Regional Experiment (SURE), reported their finding that two basic regional meteorological patterns were responsible for high sulfate concentration episodes in the northeastern United States during the summer months. The first pattern is a large, stagnating high pressure system moving from west to east across the eastern United States. The second pattern results when air is channeled from southwest to northeast between the Bermuda high and a weak cold front or stationary front extending southwest to northeast. Lavery et al. (1979) explained these two patterns as follows:

> "The first regime consists of cases where widespread stagnation occurs with a large high pressure area slowly moving eastward over the midwestern and eastern United States. Zones of polluted air collect over areas within 100-300 km of high sulfur oxide emission sources. These zones maintain themselves over periods of 1 to 4 days in warm, moist air, with light winds, around the southern and western parts of the high pressure area. The second regime appears to be conducive to long-range (> 500 km) sulfate transport and involves a channeling of air flow between the west side of the Appalachian Mountains and weak cold fronts approximately oriented west-southwest to east-northeast and traveling southeastward. The channeling appears to be combined with

> capped vertical mixing associated with subsidence around the frontal system. These episodes can last up to four days." (P. 330.)

Hidy et al. (1979) also noted that "[s]ulfate concentrations were found to be maximum in summer with minimal sulfur dioxide" (p. 76) (underlining added), thus indicating the lack of a linear relationship between regional SO_2 and regional sulfate.

On an annual basis, Mueller et al. (1979) found that the sulfate maxima in the Ohio Valley-Western Pennsylvania area shift southwestward in the fall and winter, even though the high SO_2 emission density remains in the same areas as in the summer. These winter sulfate levels in the south seem to be comparable to levels observed in the Ohio Valley-Western Pennsylvania area during the summer.

As a further part of the SURE study, the investigators applied principal component analysis techniques to the collected data base in an attempt to present the interrelationships within the data base, to verify the interpretation of dynamic processes, and to relate regional emissions and ambient sulfate levels (P. Mueller, personal communication, report forthcoming). The results of their analysis showed that the meteorological variables which correlated best with elevated sulfate levels observed during the winter were stagnation, low surface and upper wind speeds, low mixing heights, and, at the southern sites, high relative humidity. An analysis of summer (July 1978) data showed that the major component affecting sulfate variability was the diurnal cycle (see also Henry et al., 1980). This finding is thought to be related to the fact that elevated sulfate plumes are brought to the surface in greater quantity during the daytime when the mixing depth increases to plume height.

These studies make clear that meteorological parameters, coupled with as yet unknown photochemical processes, trigger, control, and sustain the appearance of elevated sulfate concentrations. While some reservoir of sulfur dioxide must obviously be present to form sulfate aerosols, the ambient SO_2 concentration and the SO_2 emission density do not appear to determine the final concentration level for the sulfate aerosol. There seems to exist no linear relationship between SO_2 emissions and ambient sulfate concentration levels.

The most recent results from several groups confirm the dominance of meteorological and other air chemical parameters over SO_2 emission factors in explaining ambient sulfate levels. These newer studies incorporate advanced multivariate linear statistical analysis (principal component analysis) and/or sophisticated trajectory models. These and other techniques are an absolutely necessary -- although still not sufficient -- prerequisite for establishing some source-receptor relationships. The positive identification of causes and source regions for sulfate aerosol observed in ambient air is still a very complex and very non-routine scientific task. But these new studies demonstrate some progress.

1. Samson (1980) developed a new, advanced methodology for objectively estimating upstream factors which could have influenced sulfate concentrations observed downwind. Using sulfate data from a number of prior investigations (including Lioy _et al_., 1977; Galvin _et al_., 1978; and Coffey _et al_., 1979) for various sites in the northeastern United States, including

New York, he then correlated concentrations of sulfate observed at those sites with three factors: estimated upstream SO_2 emission loading, upstream wind speed, and upstream mixing height. He found that downstream sulfate concentrations were insensitive to upstream mixing height, but were almost always positively correlated with the inverse of wind speed (stagnation) occurring 24 hours or more upstream of the sampling point. Most importantly, he found that "[n]o consistent relationship was evident between sulfate concentrations and potential upstream SO_2 emissions loading" (p. 1382). Again, the author states: "While there had been a significant correlation with the inverse of wind speed, no significant correlation can be discerned for emissions loading. In general, there is no consistent correlation pattern from station to station as was evident from the correlation of sulfate with the inverse of wind speed alone" (pp. 1391-92). These results confirm the importance of meteorology in explaining the fluctuations in ambient sulfate measurements in the Northeastern United States. As the author concludes: "High concentrations of sulfates appear to be consistently associated with upstream stagnation. The magnitude of its correlation with stagnation, measured as the inverse of wind speed, is not improved by adding the magnitude of SO_2 emissions." (P. 1392.)

Samson's findings have large implications for this proceeding. His study indicates that the magnitude of SO_2 emissions in the Midwest does not appear to control in any significant way ambient sulfate concentrations to the east. This lack of correlation between SO_2 emission levels and sulfate levels provides further evidence that there is not a linear relationship between upwind SO_2 emissions, on the one hand, and the transformation of SO_2 into sulfates and resulting ambient sulfate levels, on the other hand. It follows, therefore, that a reduction in SO_2 emissions from Midwestern sources in the LRT range would not necessarily result in a measurable reduction in sulfate concentrations in New York or Pennsylvania.

New York suggests that precipitation along the courses of the air parcel trajectories calculated by Samson might have scavenged sufficient sulfate particles from each air mass to explain the noncorrelation he found between upwind SO_2 emissions and downwind sulfate concentrations. Reply to Oppositions to New York's Petitions and Comments and Petitions for Reconsideration, p. 23, n.*. New York presents no evidence supporting its speculation about how rain might have affected sulfate contained in the particular air masses analyzed by Samson. In fact, if rain had scavenged the sulfate from the air masses, the sulfate would show up in wet deposition. As discussed in section II of this Statement, Wilson _et al_. (1980, 1981) have examined the wet deposition of sulfate in the Eastern United States and found that there was no linear relationship between Midwestern SO_2 emissions and wet sulfate deposition in the Northeast. Furthermore, these authors found that there exists no directional variability in annual sulfate wet deposition; air trajectories that had passed during the prior two days over Midwestern sectors or Canadian sectors deposited an amount of sulfate that was primarily determined by the total amount of precipitation. These findings are consistent with and support Samson's finding of a lack of correlation between upwind SO_2 emissions and downwind ambient sulfate levels by indicating that such emissions are not linearly related to downstream wet sulfate deposition either.

2. A very recent study by Lioy _et al_. (1981) made a number of interesting findings. The authors noted in their introduction that previous studies had indicated an association of ozone (O_3) and sulfate aerosol ($SO_4^=$) with summertime long-range transport within surface high pressure systems. They noted further that prior investigations had found that ambient ozone was a good indicator of atmospheric photochemical reactivity and that a significant portion of sulfate production appeared to be linked to reactions involving products of the photochemical smog formation process. In this study, Lioy _et al_. first found a significant association between sulfate aerosol and ozone measured at 26 regional ozone sites in the Northeast. The highest correlations were obtained for ozone measured on the same day as the sulfate, but significant correlations were also found for ozone measured one and two days prior to each sulfate measurement. These findings thus show the importance of ozone in describing the occurrence of summertime sulfate aerosol, although the authors cautioned that O_3 is probably not the only important factor in explaining such occurrence.

In order to investigate that matter further, the authors then used multivariate principal component analysis to characterize the sulfate measured at a single regional site -- Lewisburg, West Virginia -- during August 1977 and June and July 1978. The variation in daily sulfate concentration was used as the dependent variable in a step-wise regression of the principal components. The investigators found that five components, involving both local and upwind processes, had significant regression coefficients, accounting for 52% of the variation in sulfate levels (leaving the rest unexplained). The two most significant components in explaining the variation in sulfate levels were regional ozone, wind speed and ventilation (17.9%), indicating an association with upwind photochemical reactivity, and TSP mass less sulfate (16.2%), indicating an association with primary particulate emissions. Less important, though still significant components, were upwind (3-27 hours) SO_2 emissions (5.8%); local ozone and the inverse of relative humidity (5.2%), suggesting local droplet chemistry; and local temperature and absolute humidity (5.2%). These findings thus provide a further indication that meteorological and photochemical processes, as well as primary particulate emissions, are much more important in explaining the variations in ambient sulfate concentrations than are upwind SO_2 emissions (which explained less than 6% of the variance). The study indicates in particular the importance of both local and upwind photochemical reactivity to sulfate production.

3. Recent studies by Wolff et al. (1981a, 1981b) also show that the distribution of sulfate aerosol depends upon complex processes and factors beyond simply SO_2 emissions and wind direction. These investigators studied the distribution of "haze," consisting principally of sulfate aerosol, over the entire eastern United States during August and September 1979. Their preliminary findings (Wolff et al., 1981a) included the following: (1) The haze areas extended not only from the Midwest to the Northeast, but from the Gulf Coast to the Midwest. (2) The haze observed over the Gulf Coast did not form from emissions in that area, but was formed in the Midwest and Northeast in continental polar air that was then transported to the Gulf Coast area and modified by the maritime tropical environment, so that its temperature and relative humidity became similar to those observed in maritime tropical air. From there, the haze was sometimes advected back to the Midwest. (3) High ozone was generally associated with the haze.

The researchers then conducted additional analyses on the distribution and source areas for the haze observed at a sampling site in Louisiana in three episodes in August and September 1979 (Wolff et al., 1981b). The results of this analysis confirmed that the haze seen there was formed by emissions in the Midwest and Northeast and transported there, and was sometimes subsequently transported back to the Midwest. They also confirmed that elevated levels of ozone, again largely from the Northeast and Midwest, were associated with the haze. The results further showed that each episode appeared to have a significant contribution of stratospheric ozone because of the high levels of beryllium-7, a tracer of stratospheric air. All three episodes followed the passage of upper-level troughs which produce stratospheric intrusions due to tropopause folding.

Looking, for example, at the first episode in August 1979, Wolff et al. identified two major source areas for the haze. They found that the haze, accompanied by high ozone, initially formed in the eastern Midwest between August 2 and 3. On August 3, another area of haze, also accompanied by high ozone concentrations, appeared in a narrow corridor stretching from Boston to South Carolina. Because there was a northeast flow on that day, Wolff et al. concluded that it was probable that the dense emissions areas between Boston and Washington, D.C., produced this ozone and haze. This haze area was advected clockwise around a high-pressure system which formed over West Virginia on August 3. By August 4, the two haze areas had merged and stretched from Indiana to the Atlantic Coast. Supported by a closed upper air high-pressure system, the West Virginia surface high remained nearly stationary until August 9. The movements of the ozone and haze were governed, accordingly, by the clockwise circulation around the high-pressure system. Beginning on August 5, the ozone and haze traveled in a clockwise manner from the Northeast to the Southeast, arriving at the researchers' Louisiana site on August 7. From Louisiana, the haze and ozone moved northeastward on the backside of the system. The researchers also noted, based on high beryllium-7 levels, that the air mass which arrived at the Louisiana site on August 7 had a significant stratospheric air component.

It appears from the findings of Wolff et al. that a determination of the causes of regional sulfate episodes in the eastern United States must include analysis of emissions from an area at least as large as the eastern United States, as well as consideration of three-dimensional air movements and the vertical transport of ozone from the stratosphere. No existing study or model adequately performs these tasks.

In summary, these recent studies clearly indicate that there is no linear relationship between SO_2 emissions in the Midwest, their transformation into sulfates, and ambient sulfate levels in the Northeast. They show that a number of other variables -- including regional and local ozone, upstream conditions of stagnation, low surface and upper wind speeds, relative humidity, TSP mass minus the sulfate and nitrate fraction, diurnal cycle, and even vertical transport of ozone from the stratosphere -- are involved, and that some of those factors appear to be more important than the magnitude of upwind SO_2 emissions in explaining elevated sulfate levels in the Northeast. The studies relied on by New York and Pennsylvania fail to take adequate account of the nonlinear relationship involved and the importance of these other variables. Indeed, to date, no study has fully taken account of all the relevant variables and thus none has been able to explain fully on a theoretical basis the observed nonlinear relationship between SO_2 emissions and ambient sulfate concentrations. Accordingly, the evidence at present does not provide a reliable basis for quantitative conclusions about the cause of sulfate levels in the Northeast or for the establishment of source-receptor relationships.

In fact, to the extent that any conclusions can be drawn from the available data, the more recent and more sophisticated analyses indicate that the magnitude of SO_2 emissions from sources in the Midwest is not an important determinant of ambient sulfate levels in the Northeast. This seems plainly true of SO_2 emissions from the particular Midwestern sources (in the LRT range) identified by New York and Pennsylvania in this proceeding, which represent only a portion of the sources of SO_2 in the region. Thus, a reduction in SO_2 emissions from those sources might not -- and probably would not -- result in a measurable reduction in sulfate levels in New York and Pennsylvania. Only a small fraction of the SO_2 emitted is needed for conversion into sulfates. For example, 10 $\mu g/m^3$ of sulfate aerosol would be yielded by only 3 ppb of SO_2, which is at the detection limit of modern SO_2 monitoring instrumentation. Thus, to form episodic sulfate levels of 20-40 $\mu g/m^3$, only 6-12 ppb (15-30 $\mu g/m^3$) of SO_2 would be required. This is a very small amount of SO_2 on a 24-hour basis. Accordingly, even with a fairly substantial reduction in SO_2 emissions from the cited sources, a sufficient reservoir of SO_2 would remain (whether from anthropogenic or biogenic sources and whether originating in the Midwest or elsewhere) to permit sulfates to be formed and to appear in elevated levels in New York or Pennsylvania whenever the appropriate meteorological and photochemical conditions occur.

II. SUPPORT PROVIDED BY RECENT STUDIES INVESTIGATING THE CAUSES OF WET DEPOSITION OF SULFATES

The above conclusions as to the nonlinear relationship between SO_2 emissions and ambient sulfate levels and as to the dominance of meteorological and photochemical processes over SO_2 emissions in explaining those levels are supported by recent developments in analysis of wet deposition of sulfate and of other pollutant-related parameters of acidic deposition. In presenting these data, I recognize the EPA's Federal Register notice of May 1, 1981, requests parties not to make arguments based on data relating to acidic precipitation unless relevant to the question of the contribution of emissions from the identified sources to ambient air quality levels relative to the national ambient standards and PSD provisions. The evidence I will now discuss bears upon that question by confirming, in a somewhat different context, the above-noted results of the most recent studies investigating the causes of ambient sulfate levels in the Northeast, and thus bolsters the conclusion that no reliable source-receptor relationship can be established between SO_2 emission sources in the Midwest and elevated sulfate levels, much less violations of the TSP standards or increments, in New York and Pennsylvania.

A recent publication by Wilson *et al.* (1980), of which I was a co-author, reports the results of an attempt to examine concentration and wet deposition of pollutant-related ions (hydrogen, sulfate, and nitrate) at selected sites in the Northeast and Midwest, to characterize as many events as possible with respect to air mass origin, and to develop a regional pattern for the deposition of the dominant ion species. See also Wilson and Mohnen

(1981). Data for 1977-79 from the Multistate Atmospheric Power Production Pollution Study (MAP3S) were used to determine concentration and deposition on an event basis, from which monthly, seasonal, annual, and cumulative averages were developed. The results of this study showed no linear relationship between emissions of the precursor pollutants and the wet deposition of the pollutant-related ions, and thus indicate that factors other than the level of SO_2 emissions largely govern downwind effects. Some of the specific findings of this study are presented below.

An informative comparison can be made between deposition values for Whiteface Mountain, New York, located in the middle of the Adirondacks, and Champaign, Illinois, for 1978. These sites represent the eastern and western ends of a major emission region dominated by sources in the Ohio and Tennessee Valleys, and thus enable investigation of the problem of whether and to what degree the Midwest region contributes to the sulfur deposition of pristine areas such as the Adirondack region. For every precipitation event, back trajectories of the air parcels were calculated, using the Air Resources Laboratories' Atmospheric Transport and Dispersion Model (ARL-ATAD), for the two days prior to their arrival at these sites, in order to determine a dominant direction or origin of the air masses associated with these events. Sectors were used to describe the origin of the air masses.

About 50-70% of the wet deposition at Whiteface Mountain could be attributed to air masses from the "Ohio Valley/Midwest" sector (165° through 285°), with the "Canadian/Great Lakes" sector (285° through 30°) accounting for most of the remainder (nearly 30%). Since emission sources for SO_2, NO_x, etc. generally lie to the east of the Illinois station, one might expect to see a significantly different pattern in the deposition observed there. However, approximately 70% of the wet ion deposition there was attributable to the "southwest" sector (160° through 280°). These wet deposition directional patterns followed closely the directional patterns in precipitation, thus indicating that wet deposition of the major ions depends primarily on precipitation amount. Thus, while one might expect to see significant differences in precipitation chemistry as air masses from different regions arrive at a receptor site, the analysis showed the following:

Adirondack Region
Whiteface Mountain (1978)

Midwest/Ohio Valley (165° - 285° sector) 56% of the annual precipitation delivering:
62% of the annual [H+] deposition,
64% of the annual $[SO_4^{=}]$ deposition, and
65% of the annual $[NO_3^{-}]$ deposition

Canadian/Great Lakes (285° - 30° sector) 26% of the annual precipitation delivering:
31% of the annual $[H^{+}]$ deposition,
31% of the annual $[SO_4^{=}]$ deposition, and
28% of the annual $[NO_3^{-}]$ deposition

Champaign, Illinois (1978)

(160° - 280° sector) 71% of the annual precipitation delivering:
78% of the annual $[H^{+}]$ deposition,
67% of the annual $[SO_4^{=}]$ deposition, and
64% of the annual $[NO_3^{-}]$ deposition

From these data, it is quite apparent that the precipitation volume, more than any other factor, determines the amount of deposition for the three pollution-related ions. Indeed, the deposition of ions at Whiteface Mountain from the Midwest/Ohio Valley air and the Canadian/Great Lakes air does not reflect the very significant differences in the emissions that arise in those two regions. Furthermore, the Illinois wet deposition results are similar to the results at Whiteface Mountain. Thus, there seems to be no simple, straightforward relationship between emission source(s) of precursor gas(es) and receptors of the ions responsible for acid precipitation. Instead, this uniformity in directional variability of annual wet ion deposition can be explained by the concept of a regional "superbowl" -- that is, a synoptic scale air shed that results in acidic material being rather evenly deposited in all directions over a very large region.

At first glance, this "superbowl" concept seems inconsistent with the actual 1979 values for wet deposition of sulfate and nitrate ions for the MAP3S stations listed in Figure 1. As Figure 2a indicates, there were, in 1979, 1,000 mg/m^3 of sulfate ions deposited at Champaign, Illinois; 2,400 at Oxford, Ohio; 3,180 at Penn State; 2,430 at Ithaca, New York; and 1,908 at Whiteface Mountain. One is inclined immediately to jump to the conclusion that there exists a tremendous deposition gradient from west to east. That same conclusion also appears to hold for the data on nitrate deposition presented in Figure 2a. Closer scrutiny, however, reveals that these data actually support the "superbowl" concept.

One important parameter is not taken into account in Figure 2a: the amount of total annual precipitation. For example, Whiteface Mountain received about three times more precipitation than Illinois did in 1979 (104 cm vs 35.9 cm), and should, therefore, also have received greater wet ion deposi-

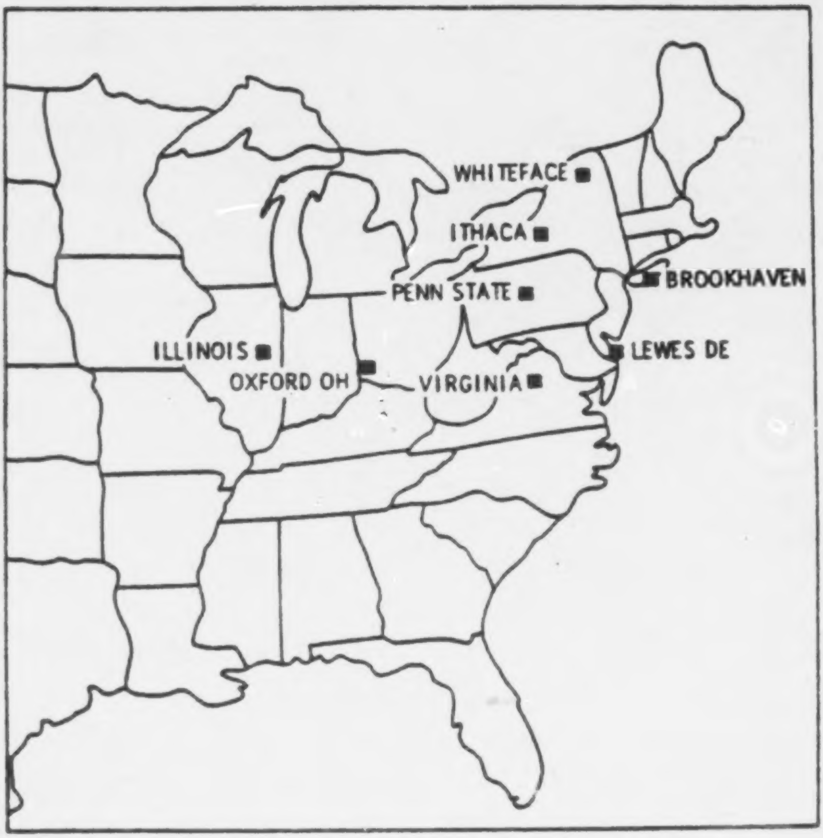

WHITEFACE
ITHACA
BROOKHAVEN
PENN STATE
ILLINOIS
OXFORD OH
VIRGINIA
LEWES DE

Figure 1: The MAP3S precipitation chemistry network site array (MacCracken, 1979)

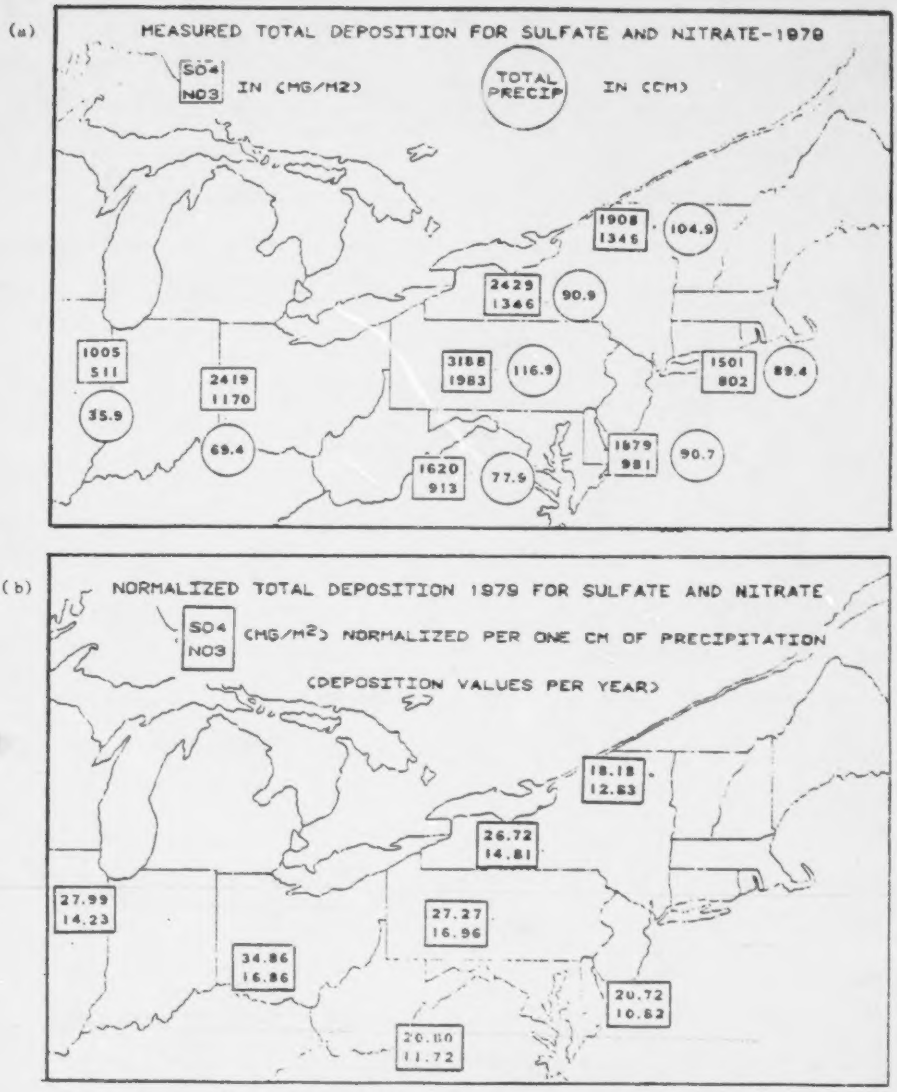
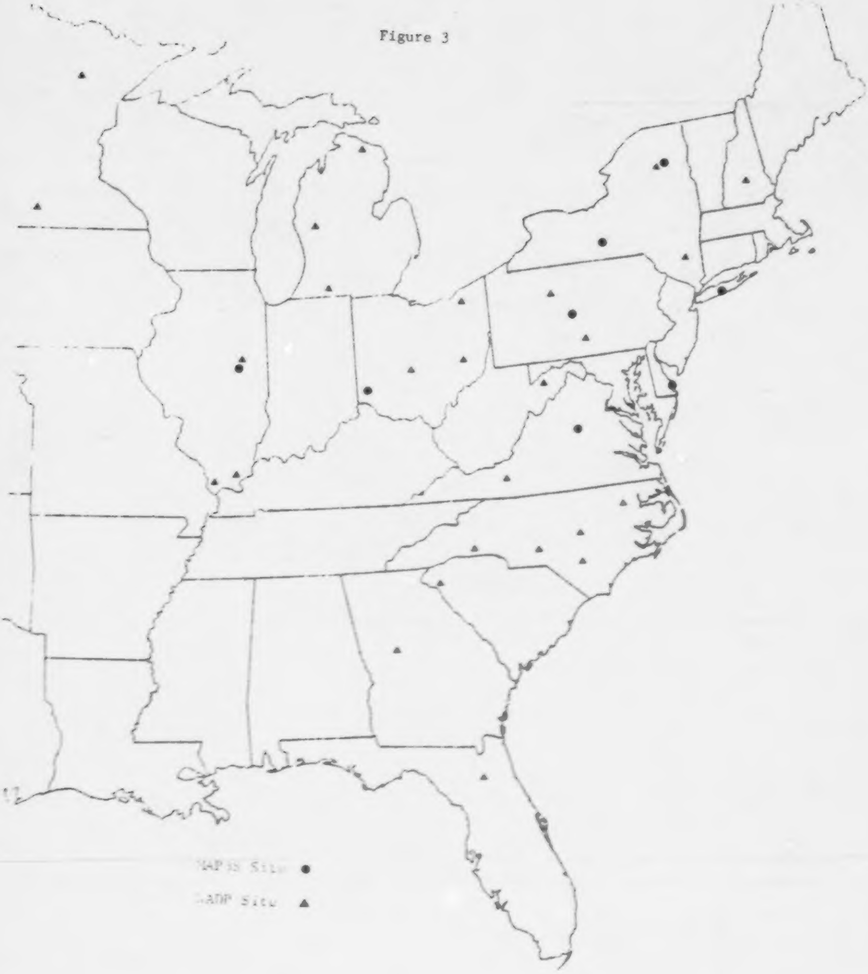

(a)
MEASURED TOTAL DEPOSITION FOR SULFATE AND NITRATE-1979
SO4
NO3
IN (MG/M2)
TOTAL PRECIP
IN (CM)
1908
1346
104.9
2429
1346
90.9
3188
1983
116.9
1005
511
35.9
2419
1170
69.4
1620
913
77.9
1679
981
90.7
1501
802
89.4
(b)
NORMALIZED TOTAL DEPOSITION 1979 FOR SULFATE AND NITRATE
SO4
NO3
(MG/M2) NORMALIZED PER ONE CM OF PRECIPITATION
(DEPOSITION VALUES PER YEAR)
18.18
12.83
26.72
14.81
27.99
14.23
27.27
16.96
34.86
16.86
20.80
11.72
20.72
10.82

Figure 2: (a) Measured, and (b) Normalized sulfate and nitrate deposition, 1979.

tion. To circumvent the problem arising from different precipitation amounts for different sites, it is necessary to normalize or standardize the wet deposition by the annual precipitation amount. The normalized deposition of sulfate and nitrate per square meter per year per centimeter of precipitation for each site is presented in Figure 2b. Figure 2b shows that no significant wet deposition gradient remains once wet deposition is standardized for the amount of precipitation. This result further supports the concept of a "superbowl" for the annual wet deposition of pollutant-related ions.

The "superbowl" concept is further supported by examining data from MAP3S and NADP sites in the eastern United States, which are shown in Figure 3. (Even though MAP3S is event-oriented, while NADP collects weekly samples, their integrated ion deposition measurements are compatible when compared over time scales in excess of one year.) Total wet deposition for each site was first normalized per centimeter of precipitation, and then, to ensure complete objectivity, spatial distributions of normalized wet deposition were analyzed using the Synagraphic Mapping System developed by the Laboratory for Computer Graphics and Spatial Analysis at Harvard University. Figure 4 shows the resulting normalized wet sulfate ion deposition pattern for 1979. As Figure 4 indicates, there is no significant west-east gradient for the pollution-related ion $SO_4^=$. Rather, there exists a rather uniform gradient in almost every direction from the major emission sources located in the Midwest/Ohio Valley. No maxima in normalized wet deposition values can be observed in the Northeastern United States that would be indicative of increased wet deposition downwind of major emission areas. (However, the effect of the Appalachian Mountains seems to be readily apparent, as evidenced by the strong

Figure 3


NAPBS Site ●
NADP Site ▲

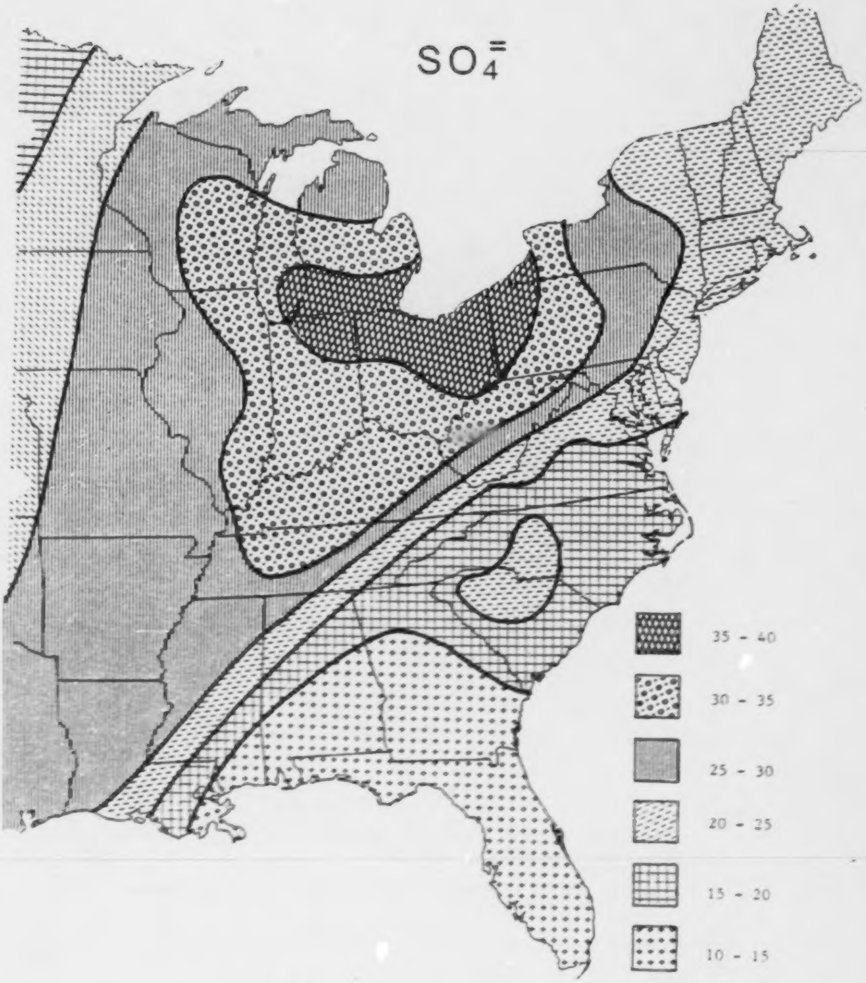

$SO_4^=$
35 - 40
30 - 35
25 - 30
20 - 25
15 - 20
10 - 15

Figure 4: $SO_4^=$ deposition (mg/m^2) normalized per cm of precipitation for 1979.

wet deposition gradients in the northwest-southeast direction.) These results are quite consistent with the "superbowl" concept, thus providing a further indication that there is no linear relationship between upwind SO_2 emissions and downwind effects.

Two European studies should also be briefly noted. Granat (1978) analyzed data from the European Atmospheric Chemistry Network (EACN) on the concentration and deposition of sulfate in rain. Some of the network's stations have been in effect for over 20 years. Granat's findings include the following: (1) Despite uncertainties, it is obvious that both concentration and deposition of sulfate in rain show considerable long-term fluctuations which are markedly different between areas in different directions and at different distances from major sulfur-emitting areas in Europe. (2) The rapid increase in both concentration and deposition observed at some stations from about 1959 to 1963 could be explained almost completely as a meteorological effect expressed as a change in frequency of winds from major sulfur emission areas associated with precipitation at these stations. Without such a meteorological interpretation, such a steep increase could be misjudged as due to changing emission rates. (3) From an ecological point of view, one can notice that even in large areas (such as Sweden and Norway) the amount of sulfur deposited will not be closely related to changes in sulfur emission rates in Europe, even for periods as long as 10 years. (4) The increase in sulfur emissions in Europe during the 10-year period from 1965 to 1975, which was about a 50% increase, led to an increase in sulfur wet deposition patterns in only a small fraction of the area covered by the network, with otherwise constant or decreasing sulfur wet deposition. Overall, Granat's assessment of the EACN data -- the oldest continuous data set on acid precipitation -- leads to the conclusion that increased sulfur emissions, even by as much as 50%, are not synonymous with increased sulfur wet deposition in a given network.

Translating these findings to the present situation would mean that an area of New York -- the Adirondacks, for example -- would not necessarily experience any measurable change in acidic deposition as a result of a change in overall SO_2 emissions for the entire Midwest. The exact emission reduction in the Midwest that would be required to see a measurable effect in sulfur deposition in the Northeast is unknown. However, from the European experience, reported by Granat, we might speculate that a reduction in SO_2 emissions of as much as 50% in the entire Midwest might not result in any measurable change in deposition in the existing Northeastern United States network.

Rodhe et al. (1979) developed a chemical model for describing the transformation of ambient SO_2 and NO_x into sulfuric acid (H_2SO_4) and nitric acid (HNO_3) during long-range transport, and compared those results with observed data from the EACN. Their model was designed to account for twenty chemical reactions that, among other things, represent the fact that, because the nitrogen oxide radicals NO and NO_2 are photochemically very active and greatly contribute to the concentrations of two species (OH and H_2O_2) involved in the oxidation of SO_2 in the atmosphere, the conversion of ambient SO_2 into H_2SO_4 is indirectly influenced by emissions of NO_x. The researchers used the model to predict how the difference between the emissions of SO_2 and NO_x that occurred in northwestern Europe in the years 1955 and 1975 would affect the summertime concentration of H_2SO_4 at three different travel times for the emitted pollutants: 10, 30, and 90 hours.

Their model simulations indicated that the increase in the concentration of sulfuric and nitric acid from 1955 to 1975 was significantly less than the increase in emissions in SO_2 and NO_x. Thus, for instance, even though the SO_2 emissions for 1975 represented a 68% increase over SO_2 emissions in 1955, the model predicted that the 1975 H_2SO_4 concentration for 10 hours travel time would exceed the 1955 concentration by only 10%; for travel times of 30 and 90 hours, the model predicted that the 1975 H_2SO_4 concentration would exceed the 1955 level by only 34% and 36%, respectively. Rodhe et al. attributed this lack of a linear relationship between SO_2 emissions and H_2SO_4 concentrations to the chemical interactions between the various species in their model.

Undue emphasis should not be placed on these findings, since they are based on an admittedly crude model. The importance of this study is that it represents an attempt to create a model for the conversion of ambient SO_2 into sulfates that recognizes at least some of the complex chemistry involved, rather than simply assuming that the conversion rate is linear. As the authors concluded, "[w]hen dealing with a coupled chemical system like the [NO_x-SO_2-NMHC system] we have studied one may not assume a proportional dependence of concentrations on emission rates" (p. 171).

In summary, the above findings regarding wet deposition support the results of the recent studies discussed in the previous section (e.g., Samson, 1980; Lioy et al., 1981; Wolff et al., 1981) by indicating that sulfate concentrations and deposition in the Northeast are not linearly related to SO_2 emissions in the Midwest but are predominantly influenced by a variety of extremely complex meteorological and photochemical factors. These results confirm that the contention of New York and Pennsylvania that the level of SO_2 emissions from Midwestern sources significantly affects sulfate levels in those States is overly simplistic and unsupported.

III. UNRELIABILITY OF AVAILABLE LONG-RANGE TRANSPORT MODELS

Apart from the outdated studies discussed in section I.A above, the only studies claimed by New York and Pennsylvania to show a relationship between SO_2 emissions from the identified Midwestern sources in the LRT range and sulfate levels in the petitioning States are those using long-range transport models. These studies include some of the more recent ORBES reports (such as the Main Report, 1981, and the report by Mahan _et al._, 1979); the Second Report of the United States-Canada Research Consultation Group on LRTAP, by Altshuller and McBean (1980); and some of the studies discussed in the Northeast Damage Report by Bridge (1981). New York claims that adequate LRT models exist and should be used by EPA in this proceeding, although its petition does not suggest which of the available LRT models should be used, much less that such a model is accurate or that it predicts that SO_2 emissions from the power plants identified by New York, individually or in the aggregate, significantly affect air quality in New York.

Several LRT models have recently been developed in an attempt to establish source-receptor relationships. For example, the Interim Report on Atmospheric Modelling (1981), prepared by Work Group 2 in accordance with the United States-Canada Memorandum of Intent on Transboundary Air Pollution, selects and describes five such models -- AES-LRT, OME-LRT, ASTRAP, ENAMAP-1, and RCDM. Such models might be considered useful for the purposes of research and regional planning. For regulatory purposes, however, no LRT model currently available is sufficiently reliable, because none can establish with the requisite degree of confidence a source-receptor relationship between SO_2 emissions in one area and sulfate concentrations or deposition in a distant location. Much less can such models quantitatively relate SO_2 emissions and TSP levels in the LRT range. EPA appears to have recognized this fact since it has not to date approved any LRT models for regulatory use.

As shown above, recent studies demonstrate that the relationship among SO_2 emissions and ambient SO_2 levels, the transformation of SO_2 into sulfate, the long-range transport of sulfate, and the resultant concentration or deposition of sulfate is not linear. Almost all LRT models, however, assume that there is such a linear relationship, and the few efforts to incorporate nonlinear parameters into models are still incomplete. It is not surprising that models assuming such a linear relationship predict that the ambient concentration and deposition of sulfate will increase proportionally as SO_2 emissions increase; that "answer" is built into the models. However, because the underlying assumption of linearity is incorrect, these models are not capable of reliably predicting elevated sulfate levels, based on SO_2 emission levels from distant sources.

The recent studies discussed earlier also indicate that complex photochemical and meteorological variables are the predominant factors in explaining the appearance of elevated sulfate levels. No LRT model available today is sufficiently sensitive to all these relevant factors. Moreover, as also noted above, Wolff et al. (1981) showed that, to accurately predict sulfate levels in the eastern United States, a LRT model must include emissions from an area at least as large as the eastern United States, must be three-dimensional, and must take into account vertical transport of ozone from the stratosphere (as well as other meteorological and photochemical factors). No such model exists at this time.

Thus, no LRT model now in existence adequately describes the mechanisms that influence the transformation of ambient SO_2 into sulfate by homogeneous and heterogeneous chemical processes, the transport of that sulfate, and the ambient concentrations or deposition of sulfate at distant sites. Present models are therefore incapable of explaining on a theoretical basis the observed nonlinear relationship among these factors, and accordingly are not sufficiently reliable for establishing source-receptor relationships.

Other problems also exacerbate the unreliability of LRT models for that purpose. Because there are no satisfactory data on a number of key variables, the models must contain arbitrary assumptions about those variables. Indeed, the current LRT models treat variables in widely different and arbitrary ways. For example, one variable on which we do not possess adequate data is the spatial and temporal resolution of wind fields. Bass (1980), in a critique of available LRT models, stated that "it appears that the principal present limitation to greater accuracy of these models is insufficient spatial and temporal resolution of the wind fields" (p. 199). It is not surprising, therefore, that the current models differ greatly in the ways they define and handle such meteorological variables. Other very fundamental variables on which there are insufficient data include the conversion rates of SO_2 to SO_4 in the homogeneous and heterogeneous phases and the dry deposition of SO_2 and sulfate. In addition, there is considerable variation in published SO_2 emission data, which, of course, constitute a crucial variable in all models. Different assumptions and variations in input for all these variables can make a great difference in the model calculations of resulting sulfate concentrations or deposition patterns.

Finally, and very importantly, no present LRT model has been systematically verified as predicting accurate results for downwind sulfate impact. Indeed, the scientific community has not yet even agreed on suitable performance evaluation criteria. Furthermore, as Bass (1980) points out, present efforts to evaluate and verify models have not approached the problem rigorously:

> "[T]o date, it would seem no group has undertaken fully the task of systematically comparing the performance of the various suggested modeling approaches with a consistent set of experiments beginning with the same meteorology, the same emissions, the same observed ambient air quality, geometry, resolution, etc., and as similar a choice of base case model parameters as is possible. . . .
>
> "It is not far amiss to describe the model sensitivity testing of regional scale and long range transport models as anarchic--many groups are repeating much the same kind of experiment, but no consistent, uniform protocols exist by which to compare and evaluate the respective performance of different models." (P. 207.)

Until such rigorous evaluation and verification studies are conducted, we will continue to lack any satisfactory knowledge about the bounds of accuracy that may be attributed to any particular model. The knowledge we do possess at this time, as indicated by the recent studies discussed above, tells us that present models do not include a sufficiently broad geographical area and do not adequately take account of various factors that appear to be more important than upwind SO_2 emission levels in determining downwind sulfate concentrations.

For all these reasons, long-range modeling is not yet at a stage of development where it can be used with sufficient confidence to establish source-receptor relationships between SO_2 emissions from particular sources or groups of sources in the Midwest and sulfate or TSP levels in the Northeast for purposes of the present proceeding. Thus, studies using such models cannot be considered as having reliably shown such a relationship.

IV. LACK OF EVIDENCE THAT SO_2 EMISSIONS FROM THE IDENTIFIED MIDWESTERN SOURCES IN THE LRT RANGE CONTRIBUTE TO VIOLATIONS OF THE NATIONAL STANDARDS OR PSD PROVISIONS FOR TSP IN NEW YORK OR PENNSYLVANIA

To this point, I have mainly addressed the question of the relationship between SO_2 emission levels in the Midwest and sulfate levels in New York and Pennsylvania, and I have shown that there is no reliable quantitative evidence of such a relationship. Of course, the principal question in this hearing, as it relates to LRT, concerns the effect of SO_2 emissions from the cited Midwestern sources on compliance with the TSP standards and PSD requirements in New York and Pennsylvania. The petitions of New York and Pennsylvania attempt to show that sulfates attributable to SO_2 emissions in the Midwest make a sufficient contribution to elevated TSP levels in those States to put those levels "over the top" of the national standards for TSP. There are several flaws in this argument.

It must be noted first that in general TSP is dominated by the influence of local sources (both point sources and area sources and both primary and secondary aerosol), and that elevated TSP levels do not appear generally to coincide with elevated sulfate levels and are not made up in large part of sulfate. New York's own calculations in its Attachment F, for example, show that at sites where violations of the national ambient standards for TSP have occurred, sulfates generally constituted only up to about 10-20% of the TSP levels,[*/] and that even at sites with the highest annual average TSP levels the corresponding sulfate levels (around 8-11 $\mu g/m^3$) were not much higher than the regional average. Of course, not all of the sulfate fraction of TSP is attributable to long-range transport. Some (1-2 $\mu g/m^3$) will be part of the overall "background" that occurs everywhere; some (about 10-20%) will be in the coarse particle mode, which is not associated with LRT; and some will be due to local influences (particularly in urban areas, which are where the monitoring stations cited by New York are located). Thus, it appears that a maximum of about 50-60% of measured sulfate levels, or 5-6 $\mu g/m^3$ on an annual average basis, could be attributed to LRT. (As discussed above, this is a more reasonable figure than the 75% cited by New York, which is based on a misinterpretation by Kolak et al., 1979.) This maximum value reflects conversion of SO_2 from all sources -- industrial, utility, home heating, etc. This value of 5-6 $\mu g/m^3$ is at the borderline of the error margin of the national ambient annual average standard for TSP (75 $\mu g/m^3$). If added to an

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[*/] New York says (e.g., on p. 35 of its petition relating to the Indiana plants) that Kolak et al. (1979) found that sulfates represented an average of 18% of TSP in the Niagara Frontier Region. That is erroneous. Kolak et al. found that sulfates represented an average of 18% of inhalable particulates in that region, but they made clear that one could not determine from that finding what percentage of TSP is made up of sulfates, since the factors are frequently different for each particle size fraction.

annual TSP level that is already near the standard, it would not necessarily cause a violation, but might be tolerated as within the error margin typically associated with such Hi-Vol measurements.

For 24-hour concentrations, the LRT component of the sulfate for a given day will, as mentioned above, be most closely represented by the lowest sulfate reading for that day at any site in the region (since higher levels will necessarily reflect local influences). Even that value must be reduced by the "natural" background and the coarse particle fraction (as well as any rural local influences). New York has not presented sufficient data on 24-hour sulfate concentrations to allow an accurate determination of the lowest reading in the region on a given day.

As discussed earlier, the evidence originating from the work of Kolak et al. (1979) needs to be treated with caution. Nevertheless, looking at the data presented in the Appendices to that report, it can be seen that even the elimination of the total fine particulate sulfate fraction would not eliminate the nonattainment status of several sites in Buffalo. For example, site 5 showed TSP readings of 293 $\mu g/m^3$ on 10/5/78 and 218 $\mu g/m^3$ on 6/27/78. The fine particulate sulfate values on those days were 10 $\mu g/m^3$ and 8 $\mu g/m^3$, respectively. Similarly, site 4 showed TSP readings of 237 $\mu g/m^3$ on 6/27/78 and 210 $\mu g/m^3$ on 9/11/78, when the fine particulate sulfate values were 17 $\mu g/m^3$ and 29 $\mu g/m^3$, respectively. Obviously, the exceedances of the national secondary 24-hour TSP standard at those sites were not significantly influenced by sulfates, let alone the LRT component of sulfates. It follows that the 24-hour nonattainment problems in Buffalo are not significantly affected by the long-range transport of sulfates due to Midwestern SO_2

emissions, and that those problems would remain even with the total elimination of that contribution.

Thus, the LRT component of sulfate does not appear to be an important factor in explaining elevated TSP levels or violations of the national ambient TSP standards. Accordingly, controlling SO_2 emissions in the Midwest in an effort to control sulfate levels in the Northeast is not the logical way to bring TSP concentrations in New York and Pennsylvania into compliance with the national TSP standards.

In any event, even assuming that New York and Pennsylvania were correct that sulfates imported from the west and southwest put TSP levels in those States "over the top" of the relevant TSP standards, nevertheless, for all the reasons discussed in the preceding sections, the available evidence still does not reliably demonstrate that those sulfate levels can be related to the levels of SO_2 emissions from sources in the Midwest. As shown above, the most recent studies demonstrate that one cannot assume a linear relationship between SO_2 emissions from Midwestern sources and sulfate levels in New York and Pennsylvania; that a number of meteorological and photochemical variables, which are not well understood and have not been adequately accounted for in the studies, appear to be more important in explaining the elevated sulfate levels; and that therefore source-receptor relationships between the emission sources and the sulfate levels cannot be confidently established. Thus, regardless of the effect of imported sulfate levels on TSP compliance in New York and Pennsylvania, those sulfate levels clearly cannot be attributed to SO_2 emissions from the particular sources named in this proceeding in the LRT range.

Accordingly, in terms of § 126 of the Act, there is no reliable evidence that SO_2 emissions from the sources identified in this proceeding in the LRT range, whether individually or in the aggregate, prevent attainment or maintenance of the national ambient air quality standards, or interfere with the required PSD provisions, in New York or Pennsylvania.

References

Altshuller, A.P., and G.A. McBean. Second Report of the United States-Canada Research Consultation Group on the Long-Range Transport of Air Pollutants (1980).

Bass, A. Modeling Long Range Transport and Diffusion. Conference Papers presented at the Second Joint Conference on Applications of Air Pollution Meteorology and Second Conference on Industrial Meteorology, pp. 193-215 (1980).

Bridge, J.E. Northeast Damage Report of the Long Range Transport and Deposition of Air Pollutants. Prepared for the Northeast States for Coordinated Air Use Management and the New England Interstate Water Pollution Control Commission (1981).

Coffey, P.E., P.J. Galvin, P.J. Samson, and J.A. Cline. Summer Aerosol Transport Study 1977. New York State Department of Environmental Conservation. AIR-P65 (8/79).

Galvin, P.J., P.J. Samson, P.E. Coffey, and D. Romano. Transport of Sulfate to New York State. Environ. Sci. & Tech. 12:580-584 (1978).

Granat, L. Sulfate in Precipitation as Observed by the European Atmospheric Chemistry Network. Atmos. Environ. 12:413-424 (1978).

Henry, R.C., G.M. Hidy, P.K. Mueller, and K. Warren. Assessing Sources, Dispersion, Chemical Transformation and Deposition of Atmospheric Sulfate over Eastern North America by Advanced Multivariate Data Analysis. 5th International Clean Air Cong., Buenos Aires, Argentina (1980).

Hidy, G.M., P.K. Mueller, and E.Y. Tong. Spatial and Temporal Distributions of Airborne Sulfates in Parts of the United States. Atmos. Environ. 12:735-752 (1978).

Hidy, G.M., P.K. Mueller, T.F. Lavery, and K.K. Warren. Assessment of Regional Air Pollution over the Eastern United States: Results from the Sulfate Regional Experiment (SURE). Paper No. IV.1. World Meteorol. Org. Symp. on the Long-Range Transport of Pollutants and Its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, Sofia, Bulgaria (Oct. 1979).

Kolak, N.P., J. Hyde, and R. Forrester. Particulate Source Contributions in the Niagara Frontier. Prepared for USEPA by the New York State Department of Environmental Conservation. EPA 902/4-79-006 (1979).

Lavery, T.F., G.M. Hidy, R.L. Basket, and J. Thrasher. Occurrence of Long-Range Transport of Sulfate Oxides in the Northeastern United States. Proc. 4th Symp. on Turbulence, Diffusion and Air Pollution, American Meteorological Society (1979).

Lioy, P.J., G.T. Wolff, J.S. Czachor, P.E. Coffey, W.N. Stasiuk, and D. Romano. Evidence of High Atmospheric Concentrations of Sulfates Detected At Rural Sites in the Northeast. J. Environ. Sci. Health A12(1&2):1-14 (1977).

Lioy, P.J., R.P. Mallon, M. Lippmann, T.J. Kneip, and P.J. Samson. The Occurrence of Ozone and Sulfate in the Northeastern U.S. Under Summertime Conditions. Paper No. 81-46.3. Air Pollution Control Association Convention, Philadelphia (June 1981).

Mahan, A.L., B.L. Neimann, and B. Phillips. Characteristics and Origins of Sulfur Dioxide, Total Suspended Particulates, and Sulfates in Western Pennsylvania. Prepared for USEPA. R-019-EPA-79 (1979).

Mueller, P.K., G.M. Hidy, T.F. Lavery, K. Warren, and R.L. Bassett. Some Early Results from the Sulfate Regional Experiment. Proc. 4th Symp. on Turbulence, Diffusion and Air Pollution, American Meteorological Society (1979).

Neimann, B.L., and A.L. Mahan. Interim Report: Impact of Long-Range Transport of Pollutants on Air Quality in the Commonwealth of Pennsylvania. Prepared for USEPA. RM-039-EPA-78 (1978).

ORBES Core Team. Ohio River Basin Energy Study (ORBES): Main Report. Prepared for USEPA. EPA-600/7-81-008 (Jan. 1981).

Rodhe, H., P. Crutzen, and A. Vanderpol. Formation of Sulfuric and Nitric Acid in the Atmosphere During Long Range Transport. Paper No. VII.3. World Meteorol. Org. Symp. on the Long-Range Transport of Pollutants and Its Relation to General Circulation Including Stratospheric/Tropospheric Exchange Processes, Sofia, Bulgaria (Oct. 1979).

Samson, P.J. Trajectory Analysis of Summertime Sulfate Concentrations in the Northeastern United States. J. Appl. Meteorol. 19:1382-1394 (1980).

Samson, P.J. Ensemble Trajectory Analysis of Summertime Sulfate Concentrations in New York State. Atmos. Environ. 12:1889-1893 (1978).

Wilson, J., and V.A. Mohnen. Spatial Variability in Wet Deposition in the Northeastern United States. Paper presented at the Conference on Long-Range Transport and Acid Rain, American Meteorological Society and Canadian Meteorological Society, Albany, New York (April 1981), and submitted for publication in International Journal of Water, Air and Soil Pollution (1981).

Wilson, J.W., V.A. Mohnen, and J.A. Kadlecek. Wet Deposition in the Northeastern United States. Atmospheric Sciences Research Center Publication No. 796 (1980).

Wolff, G.T., N.A. Kelly, and M.A. Ferman. On the Sources of Summertime Haze in the Eastern U.S. Science 211:703-705 (1981a).

Wolff, G.T., N.A. Kelly, and M.A. Ferman. Source Regions of Summertime Ozone and Haze Episodes in the Eastern United States. Paper presented at the Conference on Long-Range Transport and Acid Rain, American Meteorological Society and Canadian Meteorological Society, Albany, New York (April 1981), and submitted for publication in International Journal of Water, Air, and Soil Pollution (1981b).

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PUBLICATIONS

Volker A. Mohnen

1963 - Mohnen, V., and K. Stierstadt. Die vertielung der natürlichen radioaktivität auf das grössenspektrum der natürlichen aerosols. Z. Physik, 173, 276-293.

1964 - Mohnen, V., and H.C. Siegmann. Ein weg zur automatischen messung definierter klassen von korngrössen in staubgemischen. Staub, 24, 7, 256-261.

1965 - Mohnen, V., and K. Stierstadt. Smog und andere luftverunreinigungen. Kosmos, 4, 137-143.

1966 - Mohnen, V. Investigations into attachment properties of radioactive aerosols. J. Rech. Atm., 11, 2-3, 285.

1967 - Hohla, C., and V. Mohnen. Berechnungsmöglichkeiten für die bildung von cluster-ionen. BMwF Report K 67-74, 45 pp.

Mohnen, V. Untersuchungen über die anlagerung von neutralen und elektrisch geladenen emanations - folgeprodukten an aerosole. BMwF Report K 67-78, 55 pp.

Mohnen, V., and K. Stierstadt. Untersuchungen über radioaktive niederschläge. (IX). Atomkernenergie, 12-56, 374-376.

1968 - Mohnen, V. Anlagerungsvorgänge radioaktiver aerosole. Umschau, 5, 155.

Hofman, P., and V. Mohnen. Die wirkungsweise des akustischen teilshenzählers. Staub, 28, 9, 360-363.

Mohnen, V., and B. Vonnegut. Weather modification and air pollution. Proc. 1st Natl. Conf. on Weather Modification, Albany, NY, Apr., 228-240.

Mohnen, V., and P. Holtz. The SUNYA-ASRC aerosol detector. J. Air Poll. Control Assn., 18, 10, 667.

1969 - Mohnen, V. On the nature of tropopause ions. Planetary Electrodynamics, S. Coroniti and J. Hughes, Eds., Gordon and Breach, London, Vol. 1, Chapter II-7, 197-206.

Mohnen, V., Die radioaktive markierung von aerosolen. Z. Physik, 229, 109-122.

Rich, T., and V. Mohnen. A proposed size distribution function for natural aerosols. Proc. 7th Intl. Conf. on Condensation and Ice Nuclei, Prague, Czechoslovakia, and Vienna, Austria, Sept. 18-24, 38-50.

Mohnen, V., and J. Lodge, Jr. General review and survey of gas-to-particle conversion. Proc. 7th Intl. Conf. on Condensation and Ice Nuclei, Prague, Czechoslovakia, and Vienna, Austria, Sept. 18-24, 69-91.

1970 - Mohnen, V. Preliminary results on the formation of negative small ions in the troposphere. J. Geophys. Res., 75, 9, 1717-1721.

1970 - Mohnen, V. 5,000 join in air pollution survey. *The Conservationist*, *25*, 1, 10-15.

Fischer, W., and J. Lodge, Jr. Particle production by polymer pyrolysis: effect of carbon monoxide. Final Report to National Air Pollution Control Administration, V. Mohnen, Project Director, 21 pp.

1971 - Mohnen, V. Discussion of the formation of major positive and negative ions up to the 50 km level. *Pure and Appl. Geophys.*, *84*, I, 141-153.

Mohnen, V. Discussion of the formation of major positive and negative ions up to the 50 km level. *Mesospheric Models and Related Experiments*, G. Fiocco, Ed., 210-219.

Mohnen, V. Ionometric counters. *Atmos. Environment*, *5*, 137-145.

1972 - Schaefer, V., V. Mohnen and V. Veirs. Air quality of American homes. *Science*, *175*, 173-175.

Mohnen, V. Ion-induced and non-photochemical aerosol formation - experimental report and hypothesis. Proc. Intl. Workshop on Nucleation Theory and Its Applications, Atlanta, GA, Apr. 10-12, 161-162.

Coffey, P. Explosive growth reactions induced by the $NH_4^+(H_2O)_n$ cluster. Interim Report to National Science Foundation, V. Mohnen, Project Director, 63 pp.

Zikmunda, J., and V. Mohnen. Ion annihilation by aerosol particles from ground level to 60 km height. *Meteorologische Rundschau*, *25*, 1, 10-14.

Mohnen, V. Negative ions in air-like gas mixtures. *Pure and Appl. Geophys.*, *100*, VIII, 123-132.

1973 - Kushnir, J., H. Malkin, V. Mohnen, A. Yencha and E. McLaren. Non-photochemical aerosol formation from the anhydrous reaction between ammonia and sulfur dioxide gases. Interim Report to National Air Pollution Control Administration, 44 pp.

Kiang, C., D. Stauffer, V. Mohnen, J. Bricard and D. Vigla. Heteromolecular nucleation theory applied to gas-to-particle conversion. *Atmos. Environment*, *7*, 1279-1283.

Kiang, C., D. Stauffer and V. Mohnen. Possibilities for atmospheric aerosol formation involving NH_3. *Nature Physical Science*, *244*, 134, 53-54.

Stauffer, D., V. Mohnen and C. Kiang. Heteromolecular condensation theory applied to particle growth. *J. Aerosol Sci.*, *4*, 461-471.

Hogan, A., V. Mohnen and V. Schaefer. Comments on "Oceanic Aerosol Levels Deduced from Measurements of the Electrical Conductivity of the Atmosphere." *J. Atmos. Sci.*, *30*, 7, 1455-1460.

Mohnen, V. Introduction to the atmospheric aerosol system. Proc. Inadvertent Weather Modification Workshop, Logan, UT, Aug. 25, 255-274.

1973 - Mohnen, V. Review of Aerosols and Atmospheric Chemistry, Proceedings of a Symposium, Los Angeles, CA, Mar. 1971, G.M. Hidy, Ed. Science, 181, 837-838.

1974 - McLaren, E., A. Yencha, J. Kishnir and V. Mohnen. Some new thermal data and interpretations for the System SO_2-NH_3-H_2O-O_2. Tellus, 26, 1-2.

Kadlecek, J. Positive ion clusters involving NO_2, NH_3, SO_2 ion induced aerosol formation. Interim Report to the National Science Foundation, V. Mohnen, Project Director, 154 pp.

Mohnen, V., and E. Walther. An updated review of the literature on gas-to-aerosol conversion. Paper No. 74-150 presented at the Air Pollution Control Association 67th annual meeting, Denver, CO, Jun., 52.

Kiang, C., V. Mohnen and P. Hamill. Ternary system for the atmospheric aerosol formation. Paper No. 74-21 presented at the Air Pollution Control Association 67th annual meeting, Denver, CO, Jun., 11-12.

Kiang, C., D. Stauffer, V. Mohnen, P. Hamill and G. Walker. Nuclation theory and its atmospheric applications. Their Science and the Systems They Model, D.J. Collins, M.S. Plesset and M.M. Saffren, Eds. Proc. Intl. Colloquium on Drops and Bubbles, Pasadena, CA, Aug. 28-30, II, 506-528.

Mohnen, V. Review paper for the Subcommission IV (Ions, Aerosols and Radioactivity) of the Intl. Commission of Atmospheric Electricicity., Aug.; 10 pp.

1975 - Yencha, A., and V. Mohnen. Non-photochemical formation of atmospheric aerosols. Final Report to the U.S. Environmental Protection Agency., Dec., 70 pp.

Blanchard, D., and V. Mohnen, Eds. General statement by participants of the 2nd Inadvertent Weather Modification Workshop. Bull. Amer. Met. Soc., 56, 8, Aug., 879-881.

Mohnen, V. Testimony presented to the Subcommittee on the Environment and the Atmosphere of the Committee on Science and Technology. Inadvertent modification of the upper atmosphere: research and development relating to halocarbons and ozone depletion. U.S. House of Representatives, 94th Congress, Washington, DC, Jul., 192-195.

Mohnen, V. The environmental impact of weather modification - a strategy for implementation. Paper presented at the AAAS 141st meeting, "Science and the Quality of Life," New York, NY, Jan. 26-31.

Sorge, [illegible], V. Mohnen and P. Chylek. Solar attenuation model for an urban area - Albany, New York. Project Report to the Legislature of the State of New York, Feb., 86 pp.

1975 - Allen, E., V. Mohnen, R. Cheng, F. Grahek and K. Dayer. An investigation of aerosol size distribution in mists produced by commercial mistometers. Report prepared for the Sterling-Winthrop Research Institute, Rensselaer, NY, Feb., 78 pp.

Mohnen, V. Can ions contribute to stratospheric aerosol formation. Proc. 4th Conf. on Climatic Impact Assessment Program, NTIS DOT-TSC-OST-75-38, Cambridge, MA, Feb. 4-7, 478-491.

Birenzvige, A., and V. Mohnen. Gas to particle conversion of sulfur dioxide reaction products at low relative humidities. Interim Report to the National Science Foundation, Apr., 97 pp.

Kadlecek, J., and V. Mohnen. Time dependence of the pH of rain. Proc. 1st Intl. Symposium on Acid Preciptation and the Forest Ecosystem, USDA Forest Service General Technical Report NE-22, Columbus, OH, May 12-15, 207.

Mohnen, V. Solar energy for New York State. Position Paper presented for the Speaker of the Assembly and the Assembly Ways and Means Committee of the State of New York, May 20, 42 pp.

Yue, G., C. Kiang, V. Mohnen and E. Danielsen. The interaction of atmospheric sulfur compounds with cloud and precipitation. Interim Report to the National Science Foundation, May, 143 pp.

Kiang, C., R. Cadle, P. Hamill, V. Mohnen and G. Yue. Ternary nucleation applied to gas to particle conversion. *J. Aerosol Sci.*, *6*, 465-474.

Allen, E., V. Mohnen, R. Cheng, F. Grahek and K. Dayer. A preliminary investigation of aerosol mists produced by oral inhalers. Report prepared for the Sterling-Winthrop Research Institute, Rensselaer, NY, Feb., 96 pp.

1976 - Allen, E., E. Malawer, R. Cheng, K. Dayer, J. Kadlecek and V. Mohnen. A comparative study of aerosol mists dispensed by standard and pivot mistometer mouthpieces. Report prepared for the Sterling-Winthrop Research Institute, Rensselaer, NY, Oct., 80 pp.

Bollay, E., L. Bosart, E. Droessler, J. Jiusto, G. Lala, V. Mohnen, V. Schaefer and P. Squires. Position paper on the potential of inadvertent weather modification of the Florida Peninsula resulting from the stabilized ground cloud. Final Report to NASA, Aug.

Mohnen, V., and R. Stewart. Energy conservation via solar energy application to multi-family and commercial structures: executive summary. Part of final report submitted to NYS Energy Research and Development Authority, Aug., 39 pp.

Mohnen, V., and C. Kiang. Assessment of ion-induced stratospheric aerosol formation. Paper No. SA88A, Proc. American Geophysical Union Annual spring meeting, Washington, DC, Apr. 12-15, 36 pp.

Mohnen, V., J. Hawley, R. Cheng, T. Shen, J. Hudson and M. Current. SO_2 oxidation rate in plumes from oil-fired power plants - a laboratory study. Interim Report to the Electric Power Research Institute, Feb., 113 pp.

1976 - Yue, G., V. Mohnen and C. Kiang. Sulfur *dioxide to sulfate conversion in* the atmosphere. Atmospheric Pollution, N.M. Benarie, Ed., Amsterdam, 189-201.

Yue, G., V. Mohnen and C. Kiang. A mechanism for hydrochloric acid production in cloud. J. of Water, Air and Soil Pollution, 6, 277-294.

Roland, L., R. Whitby, V. Mohnen and P. Coffey. Measurement of background hydrocarbons in remote areas. I. Initial Experiments. ASRC-SUNY Pub. No. 395, 60 pp.

Allen, E., R. Cheng, K. Dayer, E. Malawer and V. Mohnen. Investigation of the influence of applied pressure on the aerosol size distribution produced by spray nozzles, Part I. Report prepared for the Sterling-Winthrop Research Institute, Rensselaer, NY, Jul., 196 pp.

Cheng, R., V. Mohnen, T. Shen, M. Current and J. Hudson. Characterization of particulates from power plants. J. Air Poll. Control Assn., 26, 8, 787-790.

Mohnen, V. An energy-dependent state. Chronica, Research Foundation of the State University of New York, 10, 5, 2.

Mohnen, V., A. Hogan, R. Whitby and P. Coffey. Ozone measurements in rural areas. Proc. of Non-Urban Tropospheric Composition, Hollywood, FL, Nov. 10-12, 20-1-20-8.

Whitby, R., L. Roland, V. Mohnen and P. Coffey. Measurements of background hydrocarbons in remote areas. Proc. of Non-Urban Tropospheric Composition, Hollywood, FL, Nov. 10-12, 5-1-5-21.

Stewart, R., and V. Mohnen. Solar energy development and implementation. Proc. of the UNESCO/WMO Solar Energy Symposium, Geneva, Switzerland, Aug.

1977 - Coffey, P., W. Stasiuk and V. Mohnen. Ozone in rural and urban areas of New York State, Part I. Proc. of Intl. Conf. on Photochemical Oxidant Pollution and Its Control, B. Dimitriades, Ed., EPA-600/3-77-001B, Raleigh, NC, III, 89-96.

Mohnen, V., A. Hogan, E. Danielsen and P. Coffey. Ozone measurement and meteorological analysis of tropopause folding. Proc. of Intl. Conf. on Photochemical Oxidant Pollution and Its Control, B. Dimitriades, Ed., EPA-600/3-77-001B, Raleigh, NC, III, 97-108. -

Mohnen, V. Air Quality. New York Bight Monograph 28, New York Sea Grant Institute, Albany, NY, 43 pp.

Mohnen, V., and E. Reiter. The issue of stratospheric ozone intrusion. International Conference on Oxidants, 1976. Analysis and Evidence and Viewpoints. Part III. Prepared for Environmental Services Research Laboratory, NTIS, PB-279 010, Dec., 135 pp.

Mohnen, V., A. Hogan and P. Coffey. Ozone measurements in rural areas. J. Geophys. Res., 82, 37, 5889-5895.

1977 - Danielsen, E., and V. Mohnen. Project Dustorm report: ozone transport, in situ measurements and meteorological analyses of tropopause folding. *J. Geophys. Res.*, *82*, 37, 5867-5877.

Mohnen, V. Asbestos in ambient air near Rockville Crushed Stone, Inc. Executive summary submitted to Rockville Crushed Stone, Inc., Sept., 31 pp.

Mohnen, V. Formation, nature and mobility of ions of atmospheric importance. *Electrical Processes in Atmospheres*, H. Dolezalek and R. Reiter, Eds., Dietrich Steinkopff Verlag Darmstadt, Germany, 1-17.

Allen, E., R. Cheng, A. Fountain and V. Mohnen. Particle size distribution measurements of WIN 32,784 aerosol dispensed by pivot mouthpieces. Report prepared for the Sterling-Winthrop Research Institute, Rensselaer, NY., Mar., 72 pp.

Shen, T., R. Cheng, V. Mohnen, M. Current and J. Hudson. Characterization of differences between oil-fired and coal-fired power plant emissions. Proc. of 4th Intl. Clean Air Congress, Tokyo, Japan, May 16-20, 386-391.

Kadlecek, J., V. Mohnen and J. DelSanto. Atmospheric ion molecule interactions involving chlorofluorocarbons. Final Report prepared for the Manufacturing Chemicals Association, Jan., 16 pp.

Cheng, R., K. Dayer and V. Mohnen. Field investigation of airborne dust near the Hunting Hill Quarry, Rockville Crushed Stone, Inc. Report prepared for Dunn Geoscience Corp., Latham, NY, Jan., 20 pp.

Danielsen, E., and V. Mohnen. Project Duststorm report: ozone measurements and meteorological analyses of tropopause folding. Proc. of Symposium on Atmospheric Ozone, Dresden, Germany, Aug., II, 97-114.

Mohnen, V., and G. Yue. Free hydrochloric acid in the atmosphere resulting from diffusion and scavenging processes. *Precipitation Scavenging (1974)*, R.G. Semonin and R.W. Beadle, Coords., Energy Research and Development Authority, NTIS, Springfield, VA, 208-222.

Kiang, C., V. Mohnen, D. Stauffer, P. Hamill and G. Walker. Removal processes of atmospheric aerosols and gases involving nucleation mechanisms. Precipitation Scavenging (1974), R.G. Semonin and R.W. Beadle, Coords., Energy Research and Development Authority, NTIS, Springfield, VA, 233-246.

1978 - Coffey, P., R. Whitby, W. Stasiuk, L. Husain and V. Mohnen. Ozone measurements at several rural and urban sites in New York State. *Air Quality Meteorology and Atmospheric Ozone*, A.L. Morris and R.C. Barras, Eds., American Society for Testing and Materials Technical Pub. No. 653, Philadelphia, PA, 523-535.

Kadlecek, J., T. Fiust and V. Mohnen. General composition of precipitation at Whiteface Mountain. Proc. of Lake Placid Symposium on Acid Precipitation, Lake Placid, NY.

Duce, R., and V. Mohnen. Organics Panel Report, Atmospheric Chemistry Workshop. Boulder, CO, Oct. 16-20

1978 - Mohnen, V. Report of Panel on Atmospheric Chemistry. 1980 Field Season Workshop Report, National Center for Atmospheric Research, Winter Park, CO, Nov. 28-30, NCAR/TN-133.

Chan, L., J. Kadlecek, V. Mohnen and J. DelSanto. Ion molecule interactions of atmospheric importance. Interim Report for the National Science Foundation, Dec., 145 pp.

Allen, E., T. Norton, R. Cheng and V. Mohnen. Particle size distribution measurements of mist produced by WIN 32,784 aerosol (Ktz-J-145b). Report prepared for the Sterling Winthrop Research Institute, Rensselaer, NY, Aug., 72 pp.

Falconer, P., R. Pratt and V. Mohnen. The transport cycle of atmospheric ozone and its measurement from aircraft and at the earth's surface. Man's Impact on the Troposphere - Lectures in Tropospheric Chemistry, J.S. Levine and D.R. Schryer, Eds., NASA Reference Pub. No. 1022, Sept., 109-147.

Menotti, F., J. Hudson, R. Cheng and V. Mohnen. Catalytic reactivity of airborne particulate material. Proc. of Conf. on Carbonaceous Particles in the Atmosphere, Berkeley, CA., Mar.

Bollay, R., L. Bosart, E. Droessler, J. Jiusto, G. Lala, V. Mohnen, V. Schaefer and P. Squires. Position paper on the potential of inadvertent weather modification of the Florida Peninsula resulting from neutralization of space shuttle solid rocket booster exhaust clouds. Final Report submitted to NASA, NASA Report No. 3091, 1979.

1979 - Bird, D., J. Kadlecek, V. Mohnen and J. DelSanto. ASRC liquid ion chromatograph. Report prepared for the National Science Foundation, Mar., ASRC-SUNY Pub. No. 713.

Mohnen, V. Ion composition. Position paper for the Stratospheric Workshop, NASA Goddard Space Flight Center, Greenbelt, MD, Jun. NASA Reference Pub. No. RP-1049, The Stratosphere: Present and Future.

Hogan, A., and V. Mohnen. On the global distribution of aerosols. Science, 205, 1373-1375.

Mohnen, V., J. Hudson, R. Cheng, F. Menotti, W. Stigliani and A. Pitaniello. SO_2 oxidation rate on well-characterized surfaces - a laboratory study. Final Report to the National Science Foundation, NTIS Pub. No. PB301288.

Mohnen, V., and L. Roland. Atmospheric natural hydrocarbon concentrations in the Adirondack, New York area. AGU Meeting, Washington, DC, May 28-30. Abstract published in EOS, May 1.

Winters, W., A. Hogan, V. Mohnen and S. Barnard. ASRC airborne cloud water collection system. ASRC-SUNY Pub. No. 728.

Roland, L., and V. Mohnen. Measurements of terpenic hydrocarbons (Whiteface Mt., New York). ASRC-SUNY Pub. No. 729.

1979 - Mohnen, V. Analysis of the air quality impact of the proposed refuse-derived fuel steam generation plant for Pittsfield, Massachusetts. Report submitted to the Commonwealth of Massachusetts, Berkshire Air Pollution Control Div., Springfield, MA.

1980 - Mohnen, V. Cloudwater collection from aircraft. Atmospheric Technology. in press.

Mohnen, V. Aerosol sampling for cyclo-centrifuge testing. Report submitted to Mechanical Technology, Inc., Latham, NY.

Middleton, P., C. Kiang and V. Mohnen. Theoretical estimates of the relative importance of various urban sulfate aerosol production mechanisms. Atmospheric Environment, 14, 463-472.

Chan, L., and V. Mohnen. The formation of ultrafine ion H_2O-H_2SO_4 aerosol particles through ion-induced nucleation process in the stratosphere. J. Aerosol Sci., 11, 35-45.

Mohnen, V. Review of Chapter 8 of EPA Criteria Document entitled "Air Quality Criteria for Particulate Matter and Sulfur Oxides, Volume III--Welfare Effects." Prepared for Environmental Research and Technology, Westlake Village, CA, Jun.

Mohnen, V. Review of papers presented at the WMO Symposium on the long-range transport of pollutants and its relation to general circulation including stratospheric/tropospheric exchange processes, 1979, WMO Pub. No. 538, UNIPUB.

Mohnen, V., J. DelSanto and J. Kadlecek. Nature, mobility and physico-chemical reactivity of ions in the lower atmosphere (less than 40 km). Proc. of VIth Intl. Conf. on Atmospheric Electricity, Manchester, England, Jul. 27-Aug. 1.

Chan, L.Y., and V.A. Mohnen., 1980. Ion nucleation theory. J. Atmos. Sci., 37, 2323-2331.

Suzuki, K., and V. Mohnen. Binary homogeneous nucleation theory by cluster-cluster interaction with application to the H_2SO_4-H_2O system. J. Aerosol Sci., J. Aerosol Sci., 12, 61-73, 1981.

Mohnen, V. Gas-to-particle conversion. 1981 McGraw-Hill Yearbook of Science and Technology.

Stigliani, W.M., A.M. Pitaniello and V. Mohnen. SO_2 oxidation rate on well-characterized surfaces - a laboratory study. Preliminary report to National Science Foundation, Feb. 1, 1980 to Jan. 31, 1981.

Wilson, J., V. Mohnen and J. Kadlecek, 1980. Wet Deposition in the Northeastern United States.

Wilson, J., V. Mohnen and J. Kadlecek, 1981. Wet Deposition Variability as Observed by MAP3S. Accepted for publication in Atmospheric Environment.

Lewis, L., and V.A. Mohnen, 1980. The impact of selected atmospheric parameters on solar radiation. ASRC-SUNY Pub. No. 795.

1981 - Mohnen, V. A. Acid precipitation in the eastern United States. Proceedings of the IEEE/PES 1981 Meeting, Atlanta, GA, February 1-6.

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Dr. Volker A. Mohnen
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Scotia, N.Y. 12302

November 5, 1981

The Hon. Robert T. Stafford
United States Senate
Committee on Environment and Public Works
Dirksen Building
Washington, D.C. 20510

Dear Senator Stafford:

I am sorry that I was unable to participate in the hearing held before your Committee last week on S. 1706. I am therefore submitting to you and the other members of the Committee my written comments on that bill. I would be glad to discuss with you or your staff any part of this statement or provide you with any additional evidence that you might deem necessary in considering this bill.

I am as concerned as you are in minimizing the impact of acid rain in the northeastern part of the United States. I am doubtful, however, that the measures suggested in S. 1706 will yield the effect that you so much hope for.

Very truly yours,

Volker A. Mohnen

cc: Members of the Committee on Environment and Public Works

STATEMENT OF VOLKER A. MOHNEN, Ph.D.

Director, Atmospheric Sciences Research Center
Research Professor, Department of Atmospheric Sciences
State University of New York at Albany

My name is Volker A. Mohnen. I hold a Ph.D. degree in physics, with a minor in meteorology and astrophysics, from the University of Munich. I am currently the Director of the Atmospheric Sciences Research Center and a Research Professor in the Department of Atmospheric Sciences at the State University of New York at Albany and am actively involved in research in the fields of air pollution, air chemistry and related subjects such as "acid rain." I am the author of more than 120 publications and reports dealing with those subjects. My curriculum vitae is attached.

I am submitting this statement on S. 1706, which was recently introduced by Senator Mitchell.

I. INTRODUCTION AND SUMMARY

The purpose of this bill is to protect the environment from the deleterious effects of acid deposition — that is, the wet and dry deposition of acidic materials that is often referred to as "acid rain." The bill would establish an "acid deposition impact region" consisting of the District of Columbia and the thirty-one States in the eastern United States. In general, the bill is designed to forbid increases in emissions of sulfur dioxide (SO_2) and of oxides of nitrogen (NO_x) -- two of the precursors of acid deposition -- from major stationary sources in this region and to effect a reduction of 10,000,000 tons in the annual emissions of SO_2 from sources in the region within the next ten years. The reduction in emissions required of each State would be that fraction of the 10,000,000 tons that is the ratio of all the utility emissions in the State in excess of 1.2 pounds of sulfur per million British thermal units ("BTU") to the total utility emissions in all States in the region in excess of 1.2 pounds of sulfur per million BTU. The States and sources within the region would be allowed to substitute reductions in emissions of NO_x for the mandated reductions in emissions of SO_2 at the rate of two units by weight of NO_x for each unit of SO_2.

Certain limited areas, located in parts of the northeastern United States, have been identified as suffering adverse effects from acid deposition. The major goal of the bill, as I understand it, is to protect these areas, as well as other potentially sensitive areas, from degradation caused by acid rain. Under the formula in the bill for determining the reduction in SO_2 emissions required of each State in the region, States with relatively high emissions -- such as Ohio, Indiana, and several other midwestern States -- will bear the greatest burden of reducing emissions, even though they are located hundreds of miles from the areas that have suffered adverse effects as the result of acid rain. Thus, one major, although unstated, theory of the bill seems to be that reductions in SO_2 emissions from distant sources in the Midwest will decrease acid rain in the Northeast.

There is, however, currently no scientific basis for establishing such a "source-receptor" relationship for acid rain. Atmospheric transformations and long-range transport are the only links between emission sources and receptor areas hundreds of miles away. Air mass trajectory analysis is commonly used to indicate likely source regions for airborne pollutant material. The predictions resulting from such analyses and from current transport models are not considered satisfactory and have not yet passed even the most rudimentary field validation tests.

Chemical transformations of sulfur dioxide and oxides of nitrogen in the presence of a variety of other copollutants into acidic materials that are ultimately delivered to the ground are considerably more complex than originally envisioned by atmospheric scientists. These transformations can occur in the gas phase or in the aqueous phase or a combination of both. Investigations in progress of chemical reactions of sulfur and nitrogen compounds could substantially revise our crude understanding of aqueous phase chemistry. It must be strongly emphasized that the atmospheric chemical transformation(s) of oxides of sulfur and nitrogen into materials found in wet acidic deposition appears to be not linear with respect to SO_2 and NO_x emissions. This situation presents a real problem for atmospheric modellers. It means that a control strategy based on science cannot be developed at this time. It further follows that the deposition predictions from long-range transport models, such as those selected by the U.S.-Canadian Working Group II in accordance with the United States-Canada Memorandum of Intent on Transboundary Air Pollution, are not up to the task, since they all -- directly or indirectly -- assume a linear relationship between emissions of sulfur/nitrogen compounds and sulfate/nitrate depositions.

As I will show, the hypothesis that reductions in SO_2 emissions from distant sources in the Midwest will decrease acid rain in the Northeast is not supported by the scientific research that has been conducted on acid rain. Based on our limited present understanding of acid rain, it is impossible to predict the changes, if any, in wet and dry deposition that the emission reductions that would be required by this bill would have in the environmentally sensitive areas of the Northeast. Anthropogenic emissions of sulfur and nitrogen compounds are relatively well known. Furthermore, the wet deposition of sulfate, nitrate and hydrogen ions has been reasonably well measured in recent years throughout the eastern U.S. by networks such as the National Atmospheric Deposition Program ("NADP") and the Multistate Atmospheric Power Production Pollution Study ("MAP3S"). However, the dry deposition of sulfur and nitrogen compounds is still very poorly assessed. Worst of all, the scientific community has not as yet been able to establish a causal relationship between emissions from sources or groups of sources in one part of the country and acid deposition occurring at a different time and place. For example, it is far too simple to conclude, as some have, that much of the acid rain in the Northeast is caused by SO_2 emissions in the Midwest because (1) sources with relatively high SO_2 emissions are located in some regions of the Midwest and (2) the prevailing winds in the eastern United States blow from west to east.

As adverted to earlier, our present understanding of meteorology, coupled with our present knowledge of air pollution and air chemistry, cannot identify the mechanisms and transformations at work in the processes that result in acid deposition. Research that has been done to date demonstrates that there is no linear relationship between emissions of SO_2 and NO_x and wet acidic deposition. Indeed, the one dominating factor controlling the amount of acidic material deposited by rain at a given spot seems to be the sheer volume of rain that has fallen there, rather than the level of emissions of upwind sources.

The general truism, "what goes up must come down," certainly holds true. If that is all you are interested in, then we can stop right there. But if we want to know how much we have to reduce emissions in one part of the country to achieve improvements in wet deposition of pollutant-related ions in another part of the country, then we will have to be more patient. What is needed is further, intensive research regarding acid deposition. A control program that cannot be defended on a scientific basis runs the risk of providing no significant, i.e., measurable, benefits for the areas it attempted to protect.

In the pages that follow, I will first discuss important research that has been conducted on acid rain. This research demonstrates that there is no linear relationship between upwind emissions and downwind acid rain. Next, I will explain that NO_x, hydrocarbons and other ions affect acid rain in ways that are not yet well understood, and that future research may reveal that the most effective and feasible control strategies for acid rain should focus not only on SO_2 emissions, but also on the control of other co-pollutant(s). Finally, I will briefly discuss the apparent lack of a significant link between ambient levels of sulfate aerosol and acid rain.

II. RESEARCH INDICATING THE DIFFICULTIES IN RELATING EMISSIONS TO ACID DEPOSITION

A. The Nature of Acid Rain

Sulfur dioxide, the primary focus of S. 1706, is a precursor of acid rain, since in the ambient state it can be transformed into sulfuric acid and sulfate. Sulfur dioxide, however, is not the only precursor of acid rain. Ambient NO_x and, indirectly, hydrocarbons, hydrogen peroxide, etc. also can, through transformation, provide acidic materials found in acid rain (nitric acid, nitrates, hydrochloric acid). A realistic assessment of acid rain must take into account all of these materials.

B. Research on Wet Deposition Conducted By the Atmospheric Sciences Research Center

1. Introduction

The Atmospheric Sciences Research Center ("ASRC"), of which I am Director, operates a field station at Whiteface Mountain, in the middle of the Adirondack Mountains. The 200 or so Adirondack lakes that are allegedly without fishlife because of acid rain are mostly located in the high peak areas (2000 feet and above) in the vicinity of Whiteface Mountain. ASRC's field station there has been designated by the Department of Energy as the Rural Precipitation Chemistry Center. This station is part of MAP3S and has measured precipitation quantity and quality on an event basis since the fall of 1976. In addition, the Atmospheric Chemistry Section of the National Science Foundation has supported for the past four years a variety of our research projects relating to acid rain in general and to the causes thereof in particular. The Center's research efforts are confined to the processes that cause acid rain, as opposed to its effects. We have focused our attention on the measurement of wet deposition, the identification of chemical and physical mechanisms governing the appearance of acidic material (and pollutant-related material in general) in precipitation, and the role of clouds, fogs and dews in the overall transport and transformation of gases that eventually yield sulfuric and nitric acid in precipitation.

I shall assess below the overall results of our research concerning deposition in the eastern United States, with particular emphasis on how acid rain is affected by air masses that have passed over areas with significantly different sulfur and nitrogen emission densities. The main conclusion of our research is that there is no linear relationship between emissions and wet deposition and that a source-receptor relationship between high emission density areas and wet deposition of pollutant-related ions cannot be established at this time.

The following support material is available from ASRC upon request to provide detailed insight on the findings which I discuss below:

1) Wet Deposition in the Northeastern United States. J. Wilson, V. Mohnen and J. Kadlecek. ASRC Publication 796, December 1980.
2) Wet Deposition as Observed by MAP3S. J. Wilson, V. Mohnen and J. Kadlecek. Accepted for publication in Atmospheric Environment, 1981.
3) An Analysis of Spatial Variability of the Dominant Ions in Precipitation in the Eastern United States. J. Wilson and V. Mohnen. Submitted for publication in the Journal of Water, Air, and Soil Pollution, 1981.
4) Acidity in Air and Water in a Case of Warm Frontal Precipitation. A.L. Lazrus, P.L. Haagenson, G.L. Kok, B.J. Huebert, C.W. Kreitzberg, G.E. Likens, V.A. Mohnen, W.E. Wilson and J.W. Winchester. Presented at Air Pollution Control Association, Philadelphia, PA., June 1981, Session # 13.

2. Determining the Nature of Acid Rain in the Eastern United States

The pH of a substance is an indicator of the amount of hydrogen ion (H^+) in the substance. The greater the amount of H^+ the lower the pH and the more acidic the material will be.

The measurement of pH in precipitation is not a trivial task. Its interpretation requires detailed information on sampling location, chemical and physical conditions of the surrounding terrain or surface, sampling collection procedure for precipitation, sample handling, etc.

The diagram in Figure 1 attempts to illustrate some of the informational needs that must be included with the publication of a pH value. Most measurements are made today on a weekly basis, such as in NADP, or on an event basis, such as in MAP3S. An event is defined by the beginning and the end of precipitation. Modern collectors are normally closed, and open only during precipitation through an automatic triggering device. This procedure minimizes contamination that can arise from dry deposition of dust and wet debris. Precipitation samples can be collected by ground collectors or airborne platforms. Rain that fell through the last few meters of the planetary boundary layer might be of different quality than rain that was collected at a considerable height above ground. A ground collector can be located over ocean or over land, above or below a vegetation canopy, or in an open field. Precipitation can be collected from above the planetary boundary layer (on mountain tops, etc.) or below it. Most networks today that collect precipitation for long-term monitoring are based on weekly or event-by-event sampling from ground stations that are located in an open field with no nearby obstacles.

The pH value obtained from such collection sites might have regional representativeness. All values analyzed and reported here originate from such networks. A very strict quality control procedure exists for both MAP3S and NADP.

One should keep in mind that the pH itself is insufficient to characterize precipitation quality. It is very informative to divide the ionic constituents of precipitation into three categories or components:

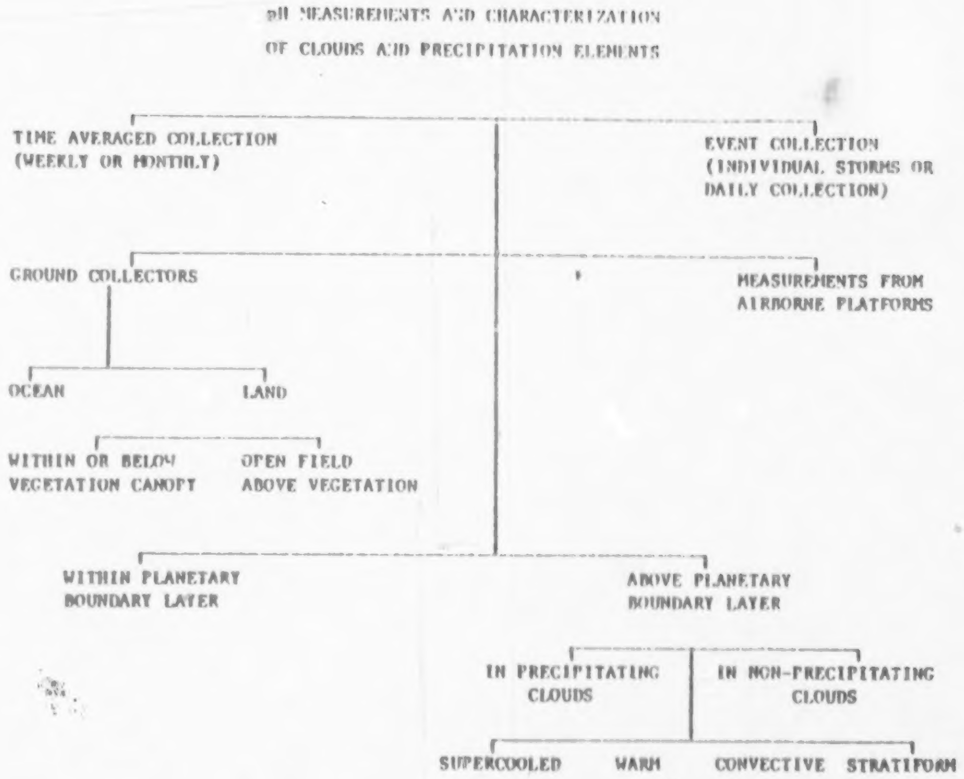

pH MEASUREMENTS AND CHARACTERIZATION
OF CLOUDS AND PRECIPITATION ELEMENTS
TIME AVERAGED COLLECTION (WEEKLY OR MONTHLY)
EVENT COLLECTION (INDIVIDUAL STORMS OR DAILY COLLECTION)
GROUND COLLECTORS
MEASUREMENTS FROM AIRBORNE PLATFORMS
OCEAN
LAND
WITHIN OR BELOW VEGETATION CANOPY
OPEN FIELD ABOVE VEGETATION
WITHIN PLANETARY BOUNDARY LAYER
ABOVE PLANETARY BOUNDARY LAYER
IN PRECIPITATING CLOUDS
IN NON-PRECIPITATING CLOUDS
SUPERCOOLED
WARM
CONVECTIVE
STRATIFORM

Figure 1. pH measurement classification.

- Soil-derived minerals: Ca^{++}, Mg^{++}, Fe^{3+}, silicate ions, etc.
- Sea salt: Na^+, Cl^-, $SO_4^=$, plus small amounts of K^+, Mg^{++} and Ca^{++}
- Atmospheric conversion products from sulfur and nitrogen bearing molecules: $SO_4^=$, NO_3^-, in addition to NH_4^+ and Cl^- (from hydrochloric acid) and, obviously, H^+.

The dominant source of data is the MAP3S. In this ongoing study, precipitation chemistry data have been obtained on an event basis beginning in 1976 for the original MAP3S collection sites of Whiteface Mountain, New York; Ithaca, New York; Pennsylvania State University; and the University of Virginia. In 1977-1978 four more stations were added to the network, which are located at Champaign-Urbana, Illinois; Lewis, Delaware (a coastal site); Brookhaven (Long Island), New York (a coastal site); and Oxford, Ohio. The location of all MAP3S stations is shown in Figure 2.

In order to determine the major ions affecting the concentration of H^+, the ionic balance between the major pollutant-related ions ($SO_4^=$, NO_3^-, NH_4^+ and H^+ itself) was determined for the 1977-79 period. This was done by analyzing these ions or pairs of ions for correlation or degree of association. Figure 3 shows the balance at Whiteface Mountain between the four dominant ions, $SO_4^=$, NO_3^-, H^+ and NH_4^+. The linear correlation coefficient of 0.95 for Whiteface Mountain indicates that a significant portion of the sulfate and nitrate could exist in the form of sulfuric and nitric acid and the appropriate ammonium salts. The linear correlation can further be improved by removing the soil components, indicated by Ca^{++} and Mg^{++}, from the cation summation, as shown in Figure 4. The correlation of 0.98 suggests that an extremely good ion balance exists whenever boundary layer influences such as soil components can be reduced.

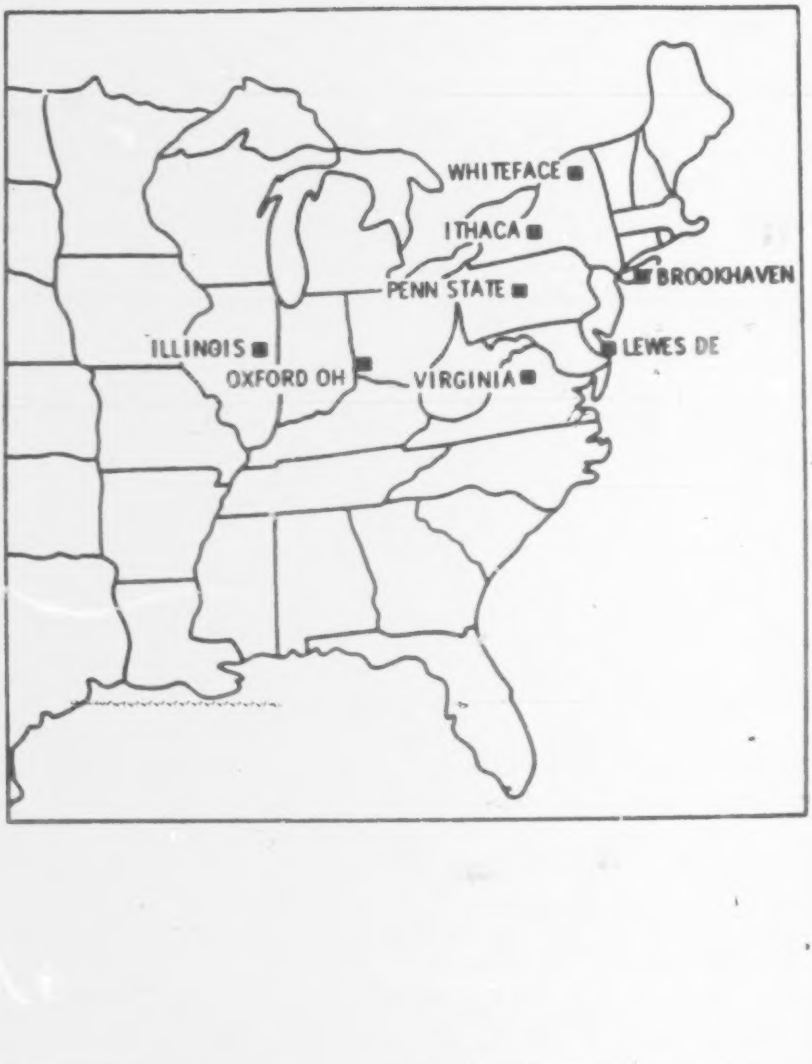

WHITEFACE
ITHACA
BROOKHAVEN
PENN STATE
ILLINOIS
OXFORD OH
VIRGINIA
LEWES DE

Figure 2. The MAP3S precipitation chemistry network site array. (MacCracken, 1979)

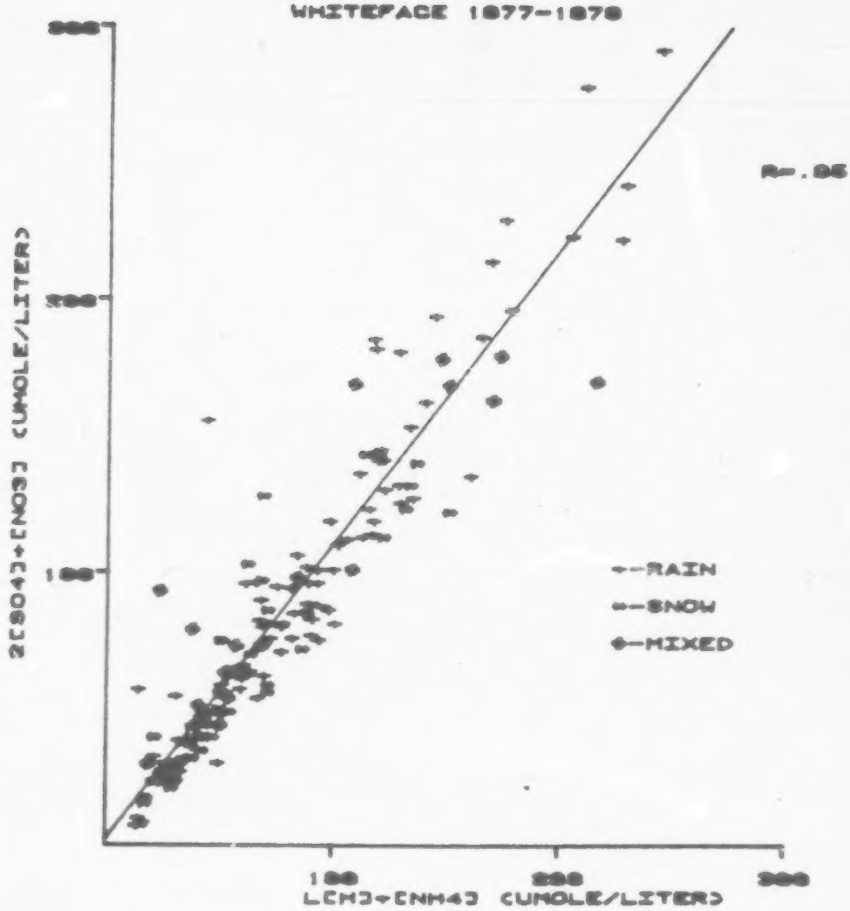


Figure 3. Hydrogen + Ammonium vs. 2(Sulfate) + Nitrate for Whiteface, 1977-1979.

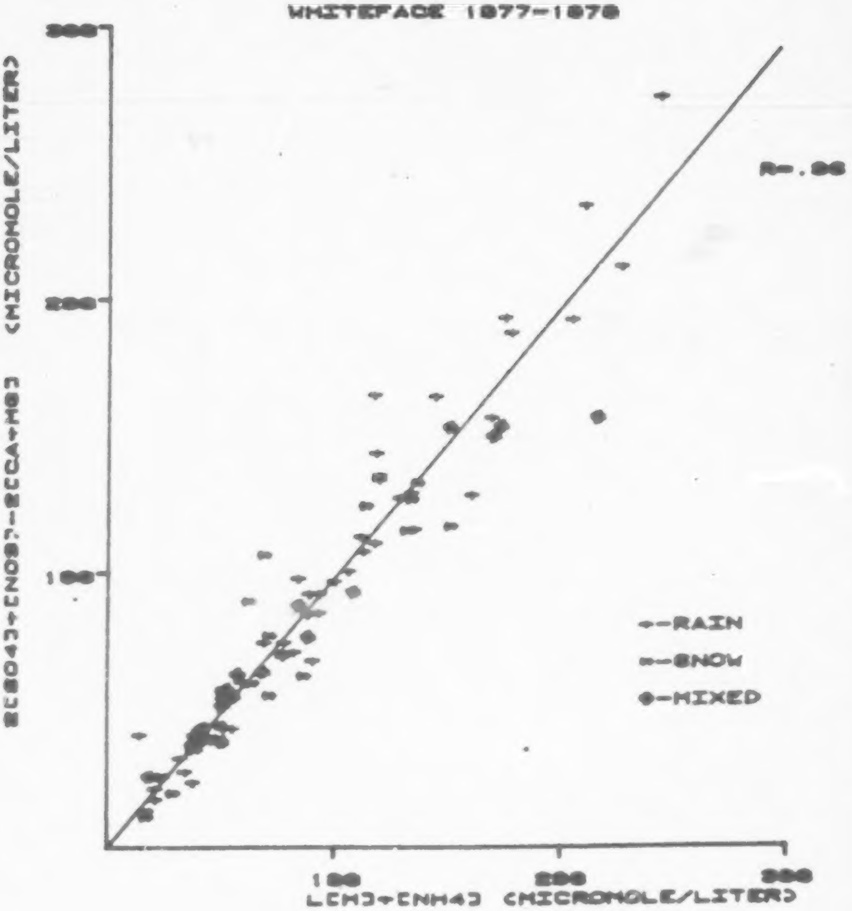


Figure 4. Hydrogen + Ammonium vs. 2(Sulfate) + Nitrate - 2 (Soil Components) for Whiteface, 1977-1979.

This procedure for examining the ionic balance was also used to determine the degree of dependency of the pH, or H^+, upon the other three major constituents. The results showed that the concentration of H^+ in precipitation depends primarily on $SO_4^=$, to a lesser extent on NO_3^-, and finally on NH_4^+. This conclusion applies to all types of precipitation for all three analyses and for the northeastern United States.

The results from Whiteface Mountain are identical to those obtained from Ithaca and from any other station in the MAP3S network. This does not mean that ammonia and hydrogen ions are the only positive ions and it does not mean that sulfate and nitrate are the only negative ions. There are, depending on the station location, a host of other anions and cations present. But it is the correlation between ammonia and hydrogen ion versus sulfate and nitrate ions that best classifies the precipitation in the northeastern United States. If one goes west of 85° longitude, the picture may be totally different. There may be almost no free hydrogen ions found in areas where the soil is alkaline. This has been demonstrated very clearly in some of the measurements of the NADP and the Canadian Network for Sampling Precipitation ("CANSAP") (see Table 1).

Knowing that the ionic balance between the hydrogen ion, ammonia, sulfate and nitrate is a good, although not a complete, indicator for acid precipitation, we now turn to a fundamental question in acid rain research: does the amount of wet ion deposition depend upon the corridor through which the air mass passed prior to a precipitation event? In terms of the assumptions underlying S. 1706, the question becomes whether acid rain in the Northeast can be blamed on air masses originating from areas of high SO_2 emissions, particularly in the Midwest.

Table 1 Example from the Canadian Network for Sampling Precipitation (CANSAP) Illustrating the Role of $SO_4^=$ and Ca^{++} in Determining Precipitation pH.

(Averages are for the three year period 1977 to 1979.)

Region Symbol	Regional Characteristics	Station	Concentration in Precipitation $SO_4^=$ (mg l^{-1})	Concentration in Precipitation Ca^{++} (mg l^{-1})	pH
A	Dry, prairie agricultural area with no regional pollution.	Lethbridge, AB Kindersley, SK Wynyard, SK	2.6 2.1 2.6	3.7 3.2 3.1	6.6 6.8 6.4
Fp	Moderately wet, native mixed forest on perphery of regionally polluted region	Gander, NF Truro, NS Seven Isles, PQ	2.3 2.6 2.5	0.2 0.3 0.1	4.6 4.5 4.4
Ap	Moderately wet, agricultural area with high regional pollution levels	Mt. Forest, ON Peterborough, ON Simcoe, ON St. Hubert, PQ Quebec City, PQ	6.1 6.7 6.3 7.7 6.8	1.3 1.4 0.8 2.2 1.2	4.4 4.1 4.1 4.2 4.2
F	Relatively dry northern forested area with no regional pollution	Fort Chimo, PQ Cree Lake, SK Fort Reliance, NT	1.2 1.2 0.9	0.2 0.4 0.2	5.1 5.1 5.3

Note: Only stations sufficiently far from the coast to neglect the oceanic influence and with more than 15 months of record are included in the table.

3. ASRC Research on the Influence of Air Mass Origin on Wet Deposition

My colleagues and I at the ASRC have devoted considerable attention to the question whether the region of origin of an air mass at a precipitation site influences the amount and nature of the wet deposition of ions observed at that site. This research is reported in the publications cited on pp. 6-7 above. We attempted to examine the concentration and wet deposition of pollutant-related ions (hydrogen, sulfate, and nitrate) at selected sites in the Northeast (including Whiteface Mountain) and in the Midwest, to characterize as many events as possible with respect to air mass origin, and to develop a regional pattern for the deposition of the dominant ion species. Wet deposition data on an event basis for 1977-79 from the MAP3S were used to determine monthly, seasonal, annual, and cumulative averages of deposition of pollutant-related ions. The results of this study showed that there is no linear relationship between emissions of the precursor pollutants and the wet deposition of the pollutant-related ions. Indeed, we found that the level of SO_2 and NO_x emissions in the region of origin of an air mass, does not appear to govern the amount of wet ion deposition at distant downwind sites. Some of the specific findings of this study are presented below.

An informative comparison can be made between deposition values for Whiteface Mountain and for Champaign, Illinois, for 1978. These sites represent the eastern and western ends of a major emission region dominated by sources in the Ohio and Tennessee Valleys, and thus enable investigation of the problem of whether and to what degree the Midwest region contributes to the deposition of pollutant-related ions that occurs in the pristine areas of the Adirondacks. For every precipitation event, back trajectories of the air parcels were calculated, using the Air Resources Laboratories' Atmospheric Transport and Dispersion Model (ARL-ATAD), for the two days prior to their arrival at these sites, in order to determine a dominant direction or origin of the air masses associated with these events. Twelve sectors covering 30° each were used to describe the origin of the air masses. This allowed differentiation between so-called "Ohio Valley/Midwest" and "Canadian/Great Lakes" air masses.

About 50-70% of the wet ion deposition at Whiteface Mountain could be attributed to air masses from the "Ohio Valley/Midwest" sector (165° through 285°), with the "Canadian/Great Lakes" sector (285° through 30°) accounting for most of the remainder (nearly 30%). Since emission sources for SO_2, NO_x, etc. generally lie to the east of the Illinois station, one might expect to see a significantly different pattern in the wet deposition observed there. However, approximately 70% of the wet ion deposition there was attributable to the "southwest" sector (160° through 280°). These wet deposition directional patterns followed closely the directional patterns in precipitation, thus indicating that wet deposition of the major ions depends primarily on precipitation amount. Thus, while one might expect to see significant differences in precipitation chemistry as air masses from different regions arrive at a receptor site, the analysis showed the following:

Adirondack Region
Whiteface Mountain (1978)

Midwest/Ohio Valley (165° - 285° sector)	56% of the annual precipitation delivering: 62% of the annual $[H^+]$ deposition, 64% of the annual $[SO_4^=]$ deposition, and 65% of the annual $[NO_3^-]$ deposition
Canadian/Great Lakes (285° - 30° sector)	26% of the annual precipitation delivering: 31% of the annual $[H^+]$ deposition, 31% of the annual $[SO_4^=]$ deposition, and 28% of the annual $[NO_3^-]$ deposition

Champaign, Illinois (1978)

(160° - 280° sector)	71% of the annual precipitation delivering: 78% of the annual $[H^+]$ deposition, 67% of the annual $[SO_4^=]$ deposition, and 64% of the annual $[NO_3^-]$ deposition

These results are shown graphically in Figures 5-8.

From these data, it is quite apparent that the precipitation volume, more than any other factor, determines the amount of deposition for the three pollutant-related ions. Indeed, the deposition of ions at Whiteface Mountain from the Midwest/Ohio Valley air and the Canadian/Great Lakes air does not reflect the very significant differences in the emissions that arise in those two regions. Furthermore, the Illinois wet deposition results are similar to the results at Whiteface Mountain. Thus, there seems to be no simple, straightforward relationship between emission source(s) of precursor gas(es) and receptors of the ions responsible for acid precipitation. Instead, this

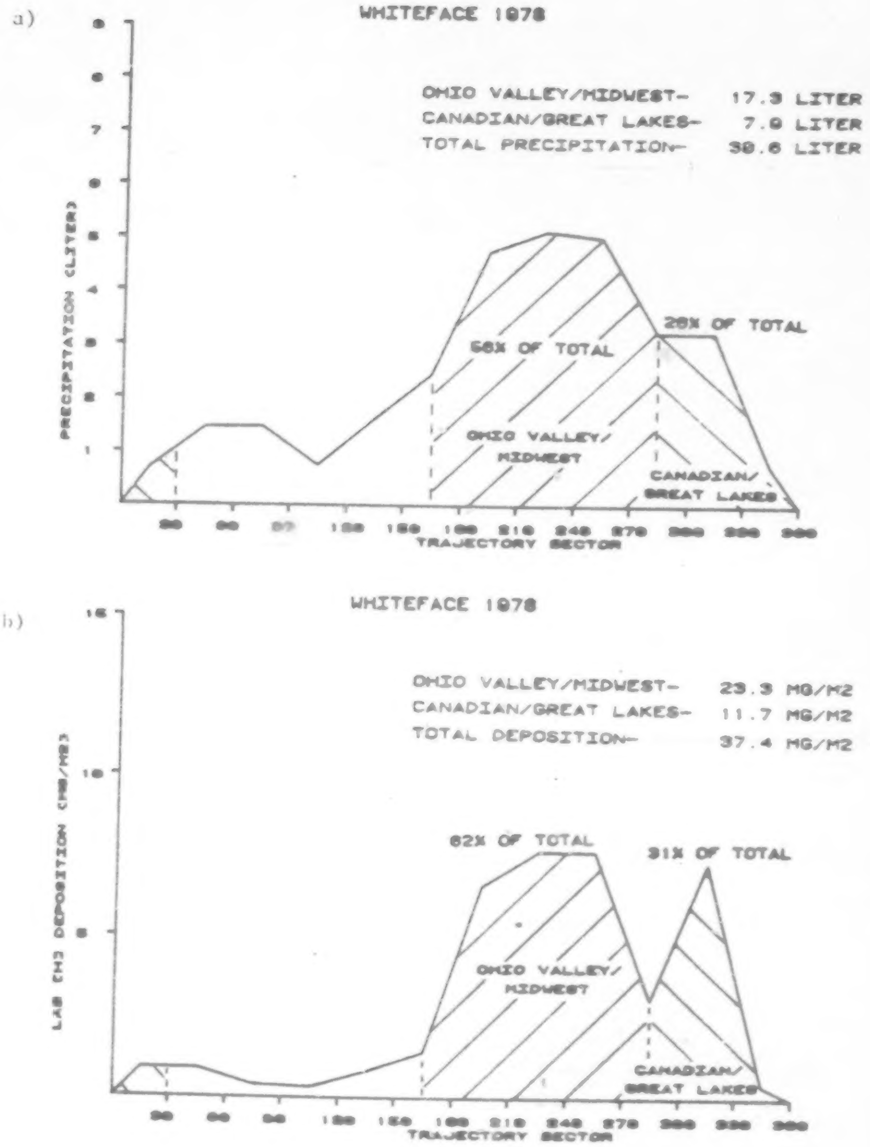


Figure 5. a) Precipitation volume, and b) Free hydrogen ion total wet deposition per 30° trajectory for Whiteface, 1978.

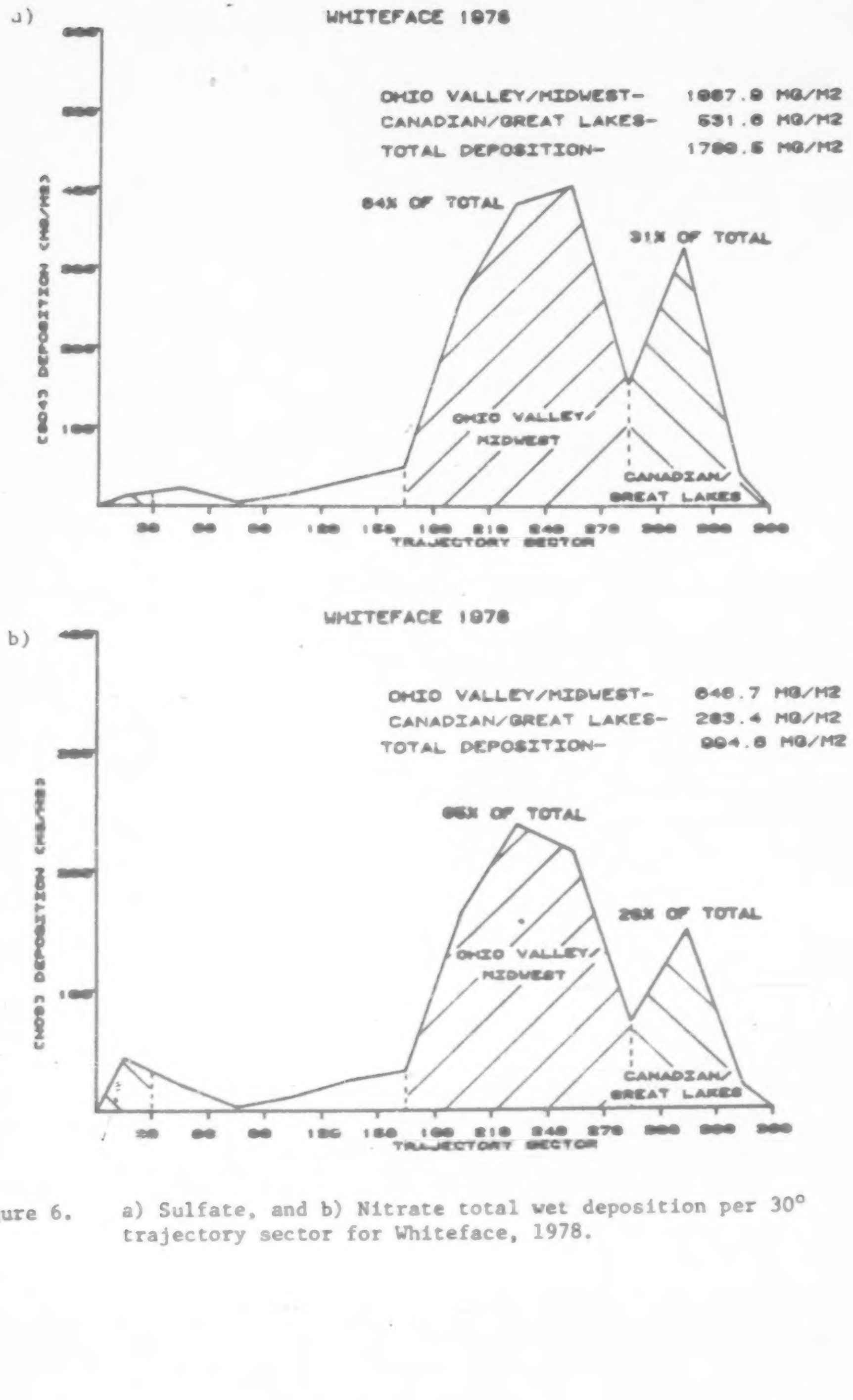


Figure 6. a) Sulfate, and b) Nitrate total wet deposition per 30° trajectory sector for Whiteface, 1978.

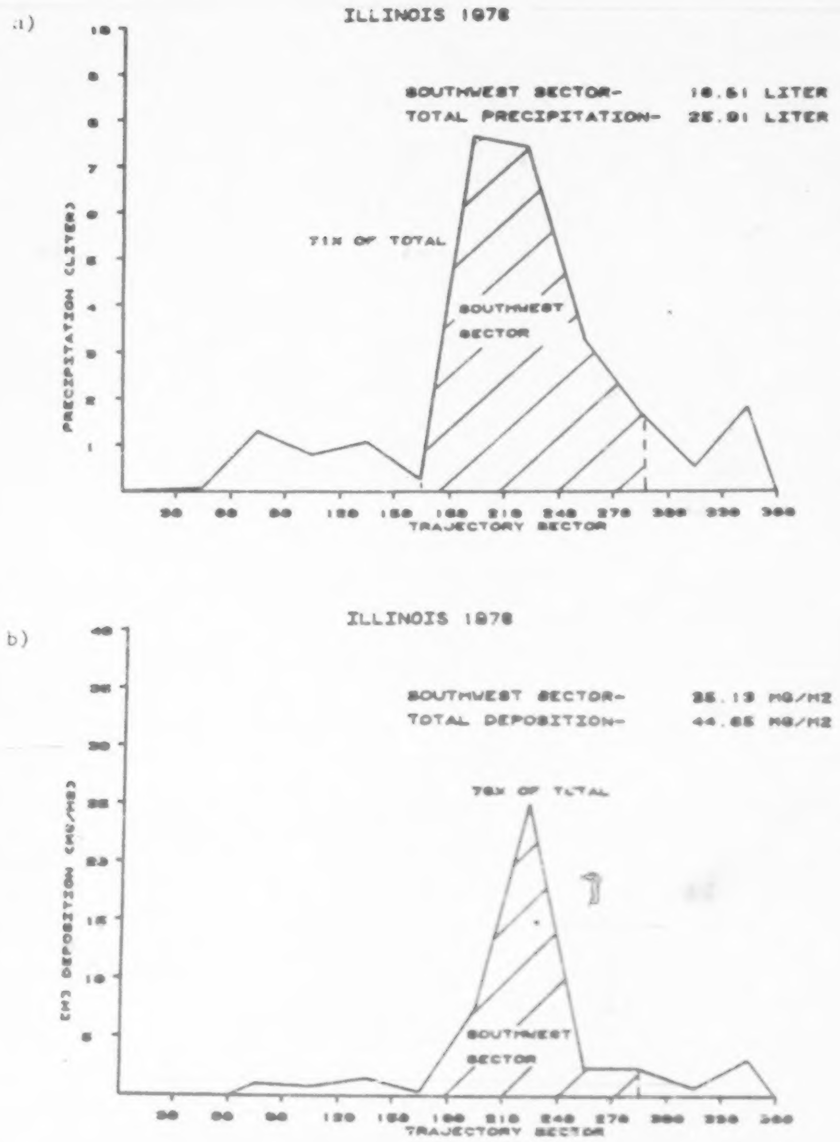


Figure 7. a) Precipitation, and b) Free hydrogen ion deposition per 30° trajectory sector for Illinois, 1978.

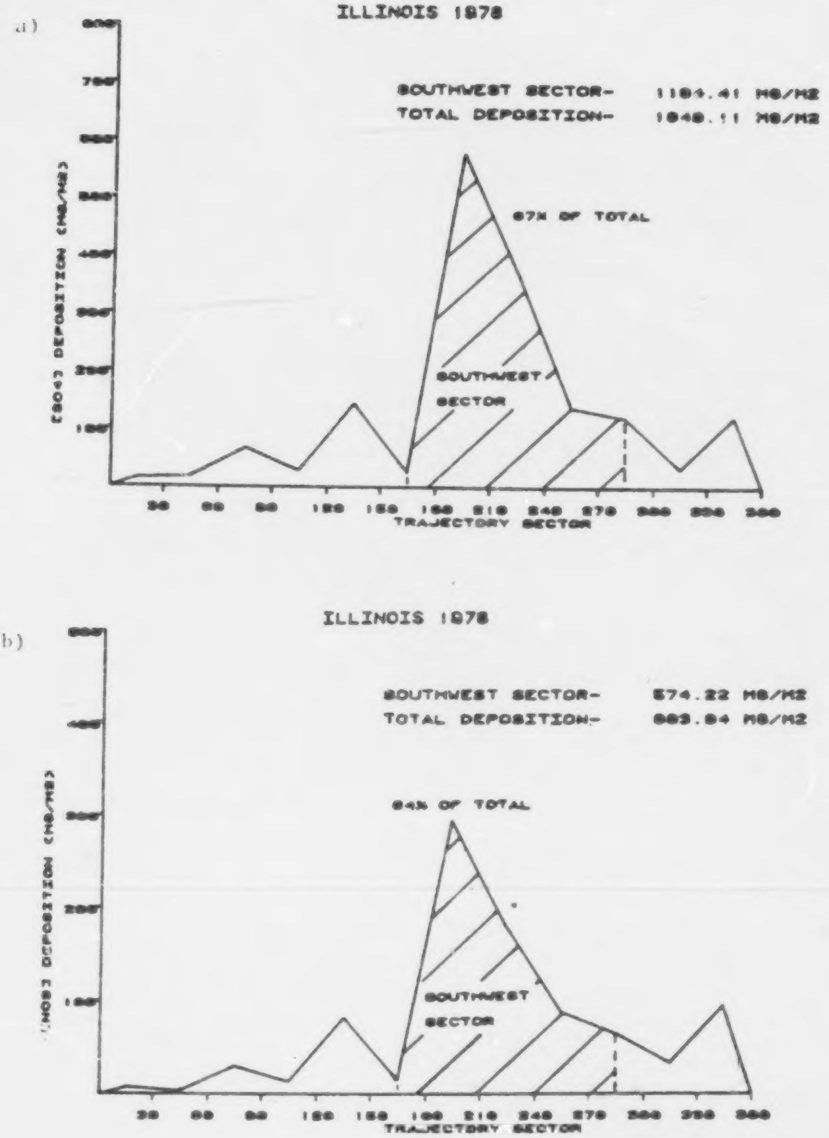
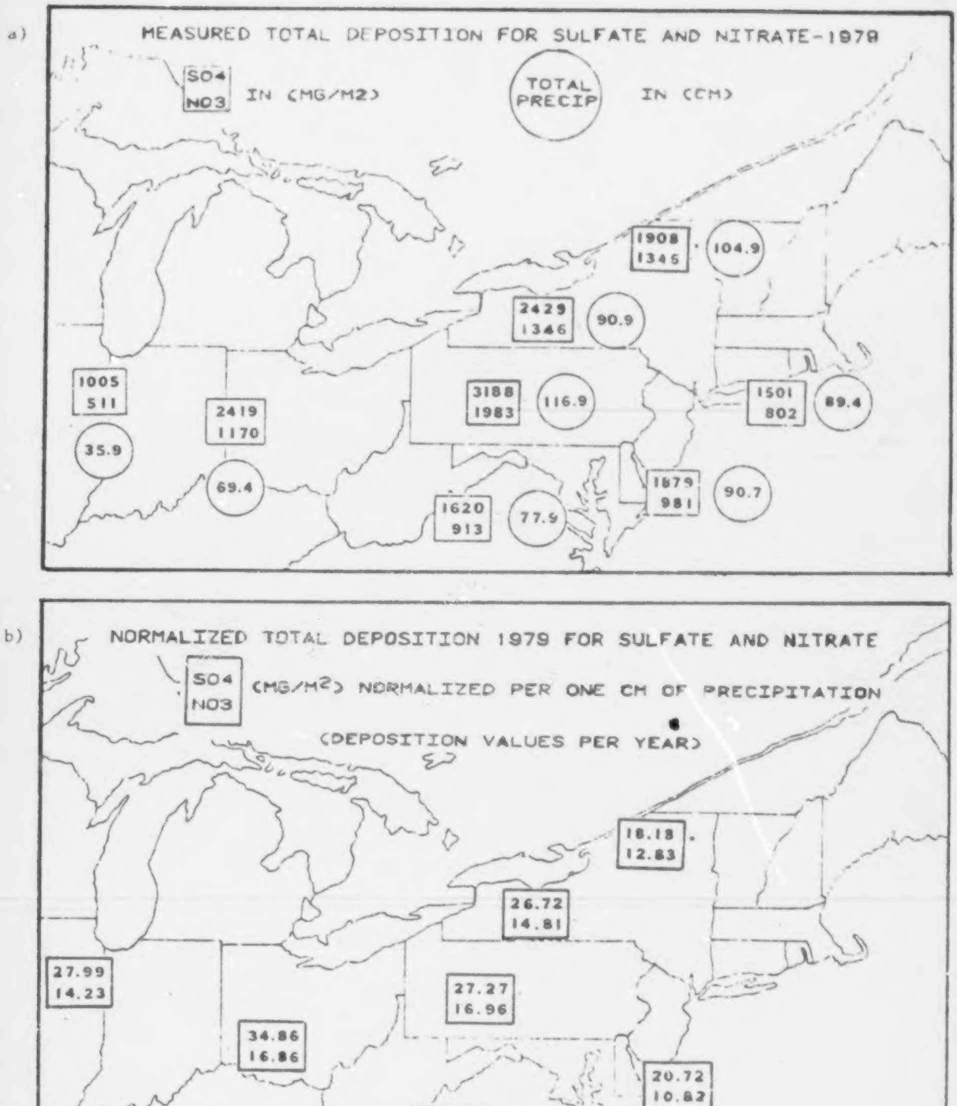


Figure 8. a) Sulfate, and b) Nitrate deposition per 30° trajectory sector for Illinois, 1978.

uniformity in directional variability of annual wet ion deposition can be explained by the concept of a regional "superbowl" -- that is, a synoptic scale air shed that results in acidic material being rather evenly deposited in all directions over a very large region.

At first glance, this "superbowl" concept seems inconsistent with the actual 1979 values for wet deposition of sulfate and nitrate ions for the MAP3S stations identified earlier in Figure 2. As Figure 9a indicates, there were, in 1979, 1,000 $mg/m^2/yr$ of sulfate ions deposited at Champaign, Illinois; 2,400 at Oxford, Ohio; 3,180 at Penn State; 2,430 at Ithaca, New York; and 1,908 at Whiteface Mountain. One is inclined immediately to jump to the conclusion that there exists a tremendous deposition gradient from west to east. That same conclusion also appears to hold for the data on nitrate deposition presented in Figure 9a. Closer scrutiny, however, reveals that these data actually support the "superbowl" concept.

One important parameter is not taken into account in Figure 9a: the amount of total annual precipitation. For example, Whiteface Mountain received about three times more precipitation than Illinois did in 1979 (104.9 cm vs 35.9 cm), and should, therefore, also have received greater wet ion deposition. To circumvent the problem arising from different precipitation amounts for different sites, it is necessary to normalize or standardize the wet deposition by the annual precipitation amount. The normalized annual wet deposition of sulfate and nitrate per square meter per centimeter of precipitation for each site is presented in Figure 9b. Figure 9b shows that no significant wet deposition gradient remains for either ion once wet deposition is standardized for the amount of precipitation. This


a)
MEASURED TOTAL DEPOSITION FOR SULFATE AND NITRATE-1979
SO4
NO3
IN (MG/M2)
TOTAL PRECIP
IN (CM)
1908
1345
104.9
2429
1346
90.9
1005
511
35.9
2419
1170
69.4
3188
1983
116.9
1501
802
89.4
1879
981
90.7
1620
913
77.9
b)
NORMALIZED TOTAL DEPOSITION 1979 FOR SULFATE AND NITRATE
SO4
NO3
(MG/M2) NORMALIZED PER ONE CM OF PRECIPITATION
(DEPOSITION VALUES PER YEAR)
18.18
12.83
26.72
14.81
27.99
14.23
27.27
16.96
34.86
16.86
20.72
10.82
20.80
11.72

Figures 9a & 9b. a) Measured, and b) Normalized sulfate and nitrate deposition, 1979.

result supports the concept of a "superbowl" for the annual wet deposition of pollutant-related ions.

The "superbowl" concept is also supported by examining data from MAP3S and NADP sites in the eastern United States, which are shown in Figure 10. (Even though MAP3S is event-oriented, while NADP collects weekly samples, their integrated ion deposition measurements are compatible when compared over time scales in excess of one year.) Total annual wet deposition for each site was first normalized per centimeter of precipitation, and then, to ensure complete objectivity, spatial distributions of normalized wet deposition were analyzed using the Synagraphic Mapping System developed by the Laboratory for Computer Graphics and Spatial Analysis at Harvard University.

Figures 11 and 12 show the resulting normalized annual wet deposition pattern for the sulfate ($SO_4^=$) and nitrate (NO_3^-) ions for 1979. As these figures indicate, there is no significant west-east gradient for the pollutant-related ions $SO_4^=$ and NO_3^-. Rather, there exists a uniform gradient in almost every direction from the major emission sources located in the Midwest/Ohio Valley. No maxima in normalized annual wet deposition values can be observed in the northeastern United States that would be indicative of increased wet deposition downwind of major emission areas. (However, the effect of the Appalachian Mountains seems to be readily apparent, as evidenced by the strong wet deposition gradients in the northwest-southeast direction.) Furthermore, the annual precipitation pattern in the eastern United States, which is presented in Figure 13, shows up as a strong "forcing mechanism" in explaining the independently derived annual wet ion deposition pattern. (Compare Figure 13 to Figures 11 and 12.) These results support the

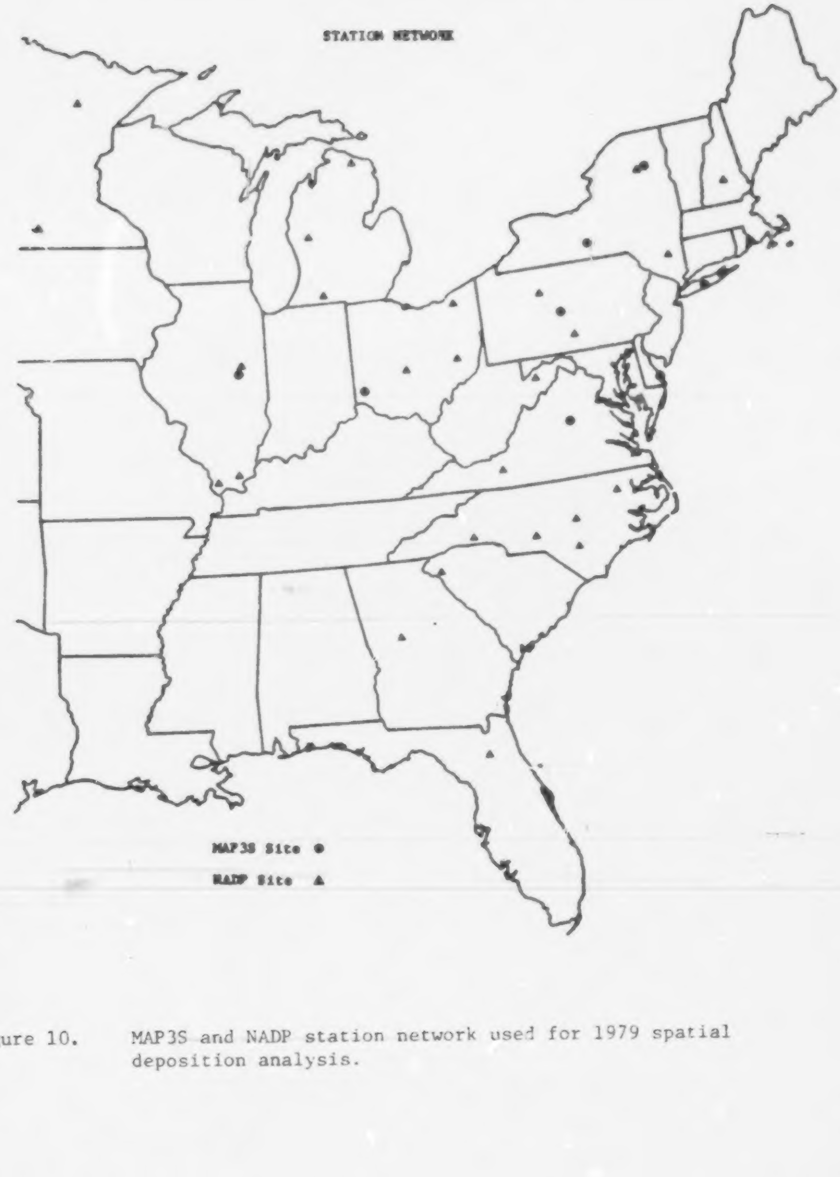

STATION NETWORK
MAP3S Site ●
NADP Site ▲

Figure 10. MAP3S and NADP station network used for 1979 spatial deposition analysis.

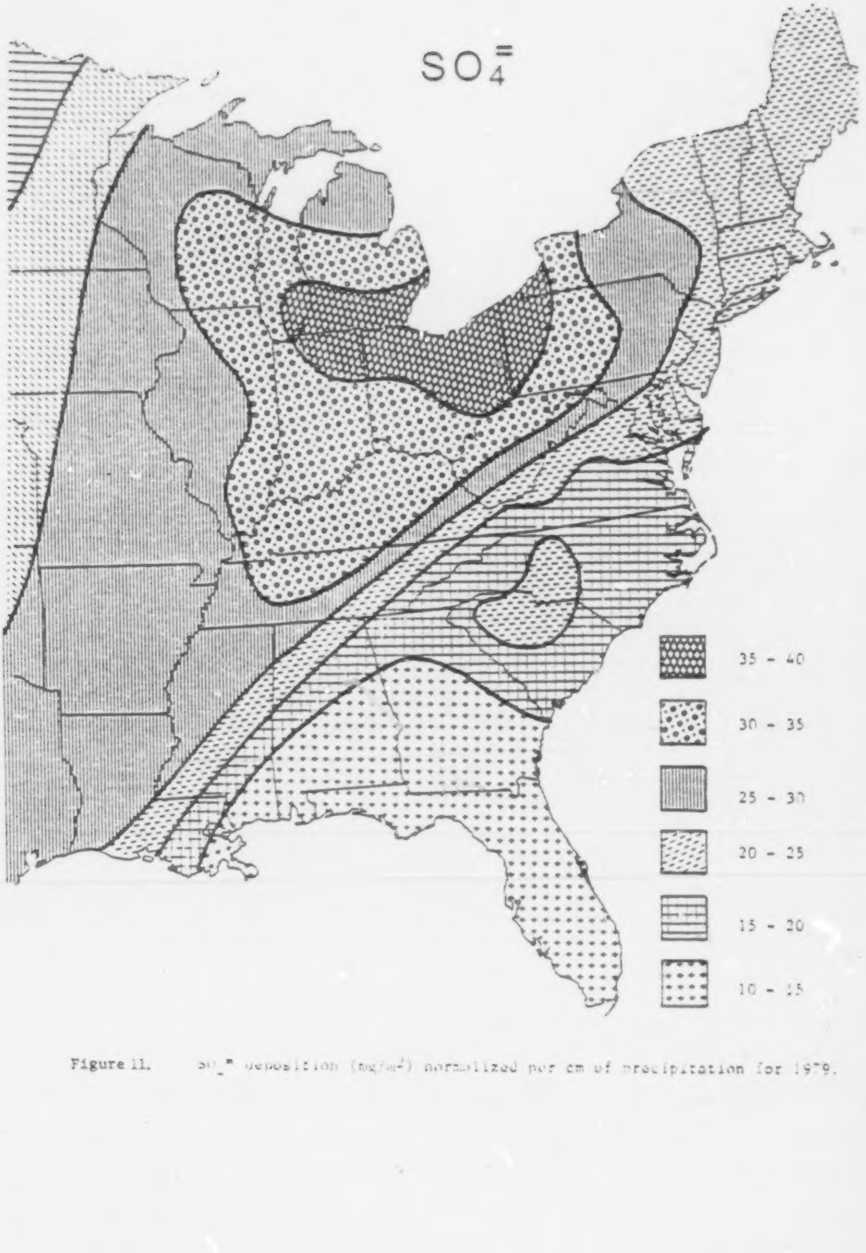

$SO_4^=$
35 - 40
30 - 35
25 - 30
20 - 25
15 - 20
10 - 15

Figure 11. $SO_4^=$ deposition (mg/m²) normalized per cm of precipitation for 1979.

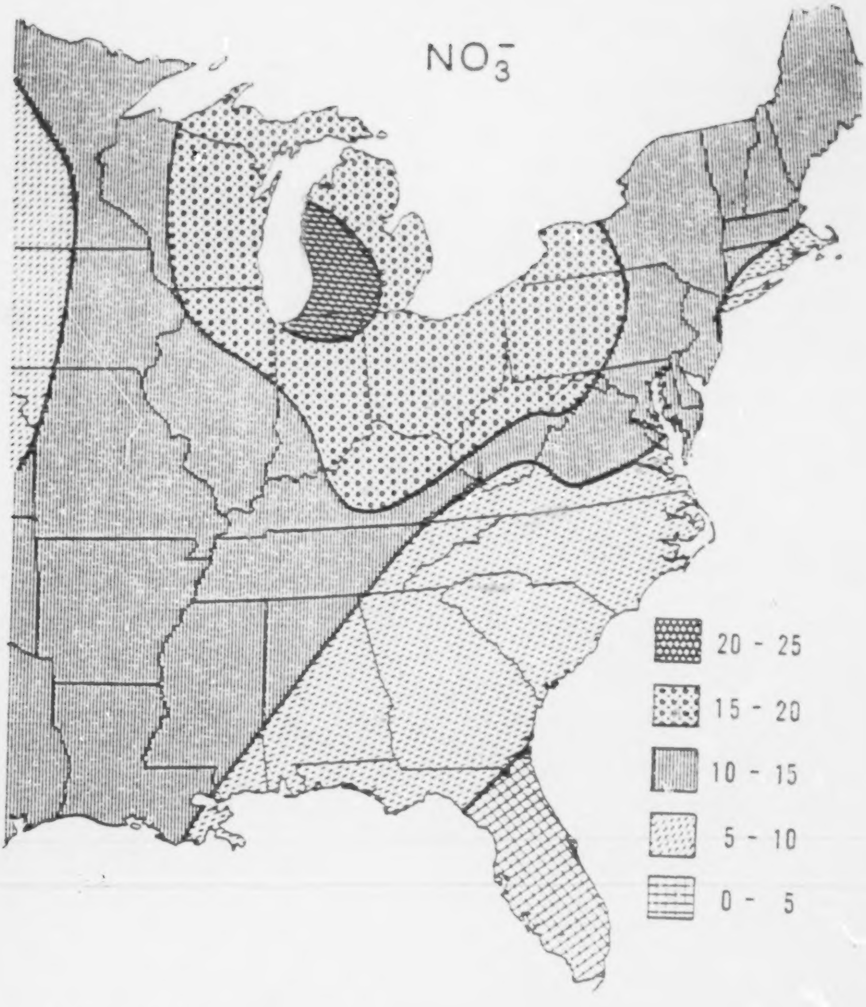

NO$_3^-$
20 - 25
15 - 20
10 - 15
5 - 10
0 - 5

Fig. 12. NO$_3^-$ deposition (mg/m^2) normalized per cm of precipitation for 1979

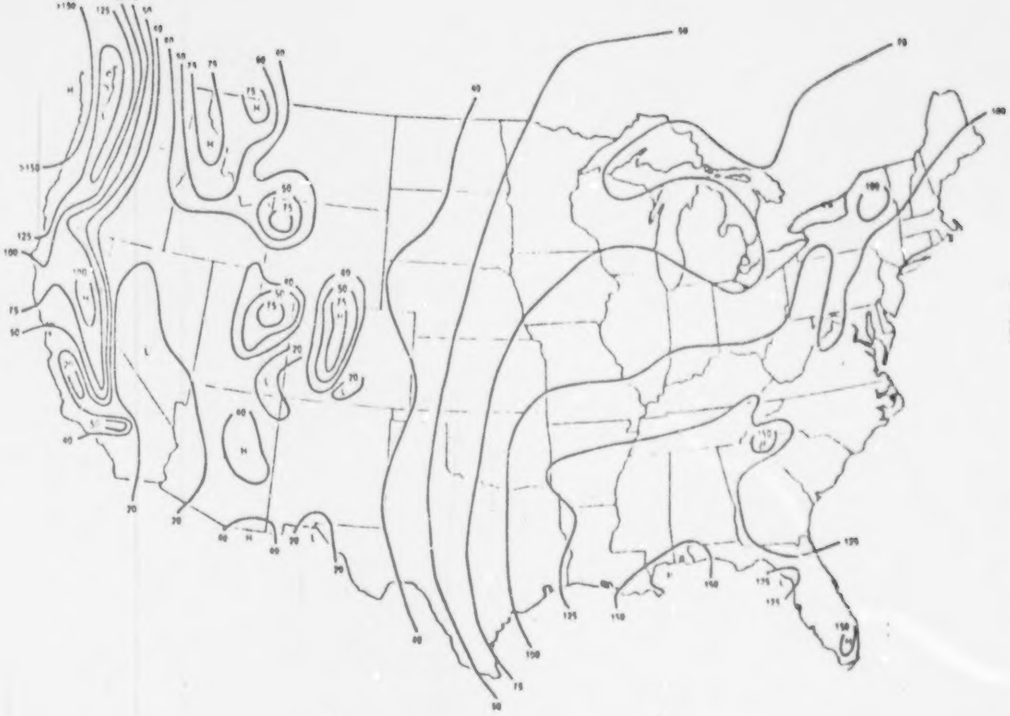

>150
125
100
75
50
60
70
80
90
H
L
100
125
150
175

Figure 13.

APPROXIMATE MEAN ANNUAL PRECIPITATION (centimeters)
(from Wisniewski and Keitz (1981), personal communication)

"superbowl" concept, thus providing a further indication that there is no linear relationship between upwind SO_2 or NO_x emissions and downwind wet deposition. Indeed, the relationship between the high emission density areas of the Midwest and downwind deposition in the Northeast cannot be readily discerned.

A slightly more complex picture emerges for the hydrogen ion deposition (H^+), as shown in Figure 14. The free hydrogen ion deposition results from the contribution of various constitutents including sulfuric acid, nitric acid, ammonium and soil-related components such as calcium and magnesium. Therefore, its spatial distribution can be expected to be more complex than the normalized wet deposition pattern of $SO_4^=$ or NO_3^- alone. This is indeed verified in Figure 14. Localized maxima in H^+ wet deposition are evident and a strong gradient emerges to the west of 85° longitude. One can speculate that soil-related material scavenged by precipitation might be responsible for the apparent change in free hydrogen ion deposition. This view is strongly supported by the normalized wet deposition emerging from the ammonium ion, as shown in Figure 15. The normalized NH_4^+ deposition is largely a function of natural sources. Increased NH_4^+ ion deposition to the west of 85° longitude correlates well with the decrease in free hydrogen ion deposition, since NH_4^+ acts as a "neutralizing agent." (See also Table 1.)

These results demonstrate the complexity of acid precipitation. The relatively uniform west-east wet deposition pattern for sulfate and nitrate ions indicates that science cannot, at the present time, determine to what degree, if any, reductions in emissions of SO_2 and NO_x in a given region will ameliorate to any extent acid precipitation in a different area. Without more

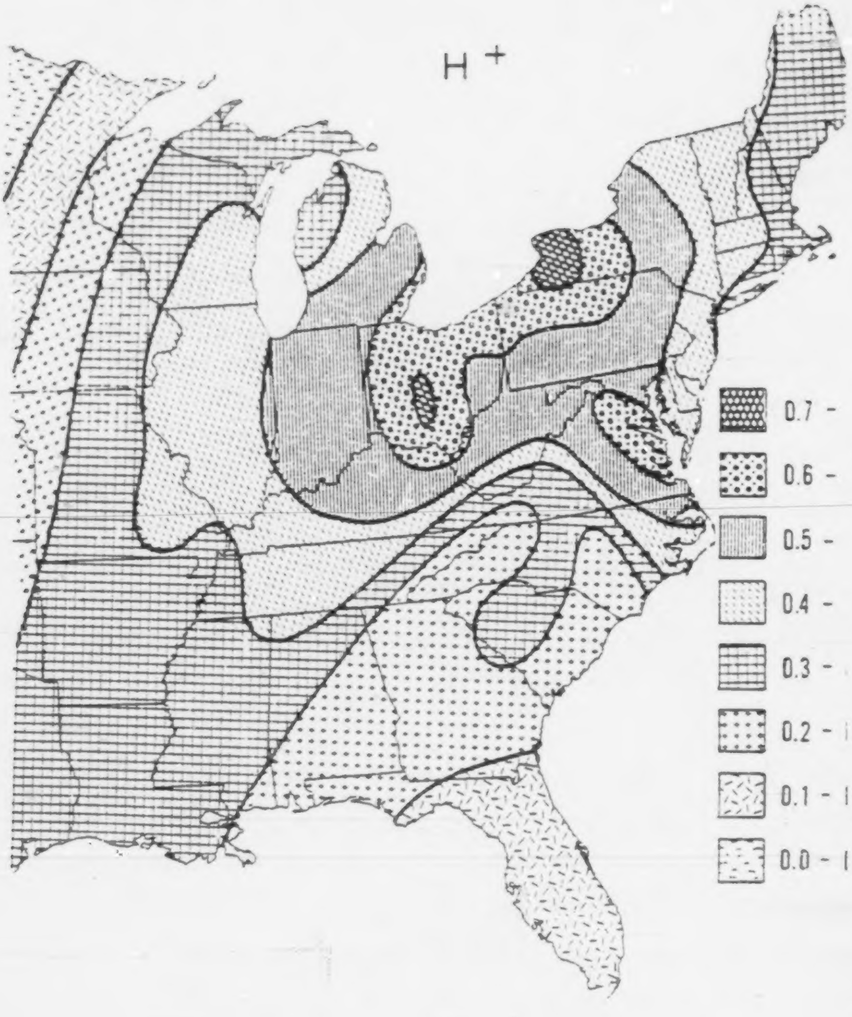

H +
0.7 -
0.6 -
0.5 -
0.4 -
0.3 -
0.2 -
0.1 -
0.0 -

Figure 14. H^+ deposition (mg/m^2) normalized per cm of precipitation for 1979.

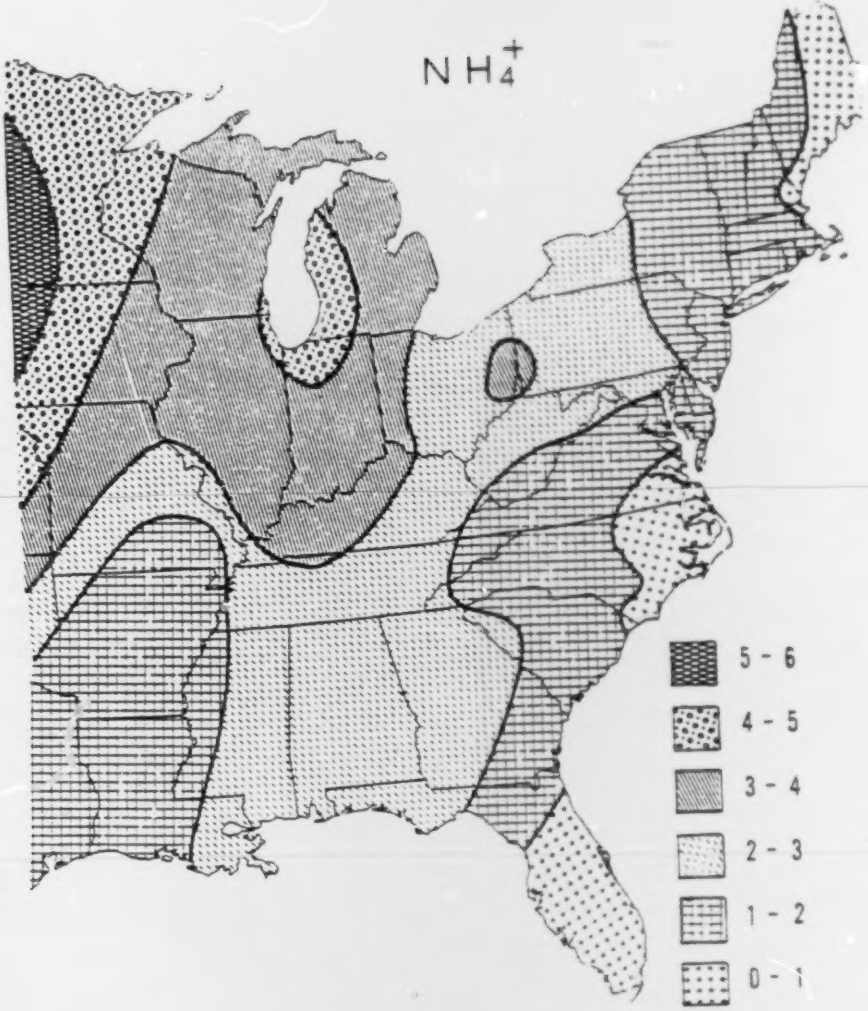

NH_4^+
5 - 6
4 - 5
3 - 4
2 - 3
1 - 2
0 - 1

Figure 15. NH_4^+ deposition (mg/m^2) normalized per cm of precipitation for 1979 research, an effective control strategy for acid rain, based on science, cannot be devised.

C. European Research Concerning Acid Rain

An important European study should also be briefly noted. Granat (1978)[*/] analyzed data from the European Atmospheric Chemistry Network (EACN) on the concentration and deposition of sulfate in rain. Some of the network's stations have been in effect for over 20 years. Granat's findings include the following: (1) Despite uncertainties, it is obvious that both concentration and deposition of sulfate in rain show considerable long-term fluctuations which are markedly different between areas in different directions and at different distances from major sulfur-emitting areas in Europe. (2) The rapid increase in both concentration and deposition observed at some stations from about 1959 to 1963 could be explained almost completely as a meteorological effect expressed as a change in frequency of winds from major sulfur emission areas associated with precipitation at these stations. Without such a meteorological interpretation, such a steep increase could be misjudged as due to changing emission rates. (3) From an ecological point of view, one can notice that even in large areas (such as Sweden and Norway) the amount of sulfur deposited will not be closely related to changes in sulfur emission rates in Europe, even for periods as long as 10 years. (4) The increase in sulfur emissions in Europe during the 10-year period from 1965 to 1975, which was about a 50 percent increase, led to an increase in sulfur wet deposition patterns in only a small fraction of the area covered by the network, with

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[*/] Sulfate in Precipitation as Observed by the European Atmospheric Chemistry Network. L. Granat. Atmospheric Environment 12:413-424, 1978.

otherwise constant or decreasing sulfur wet deposition. Overall, Granat's assessment of the EACN data -- the oldest continuous data set on acid precipitation -- confirms the conclusion that there is no linear relationship between sulfur emissions levels and sulfur wet deposition levels.

Translating these findings to the situation with respect to S. 1706 would mean that an area of the Northeast -- the Adirondacks, for example -- would not necessarily experience any measurable change in acidic deposition as a result of a change in overall SO_2 emissions for the Midwest. Based on our present scientific knowledge, it is impossible to determine the emission reduction in the Midwest that would be required to see a measurable effect in sulfur deposition in the Northeast. The European experience, reported by Granat, suggests that a reduction in SO_2 emissions of even as much as 50 percent in the Midwest might not result in any measurable change in deposition in the northeastern United States.

D. Conclusion on Wet Deposition

The studies on wet deposition that I have discussed demonstrate that the underlying assumption of S. 1706 -- that a specified reduction in SO_2 emissions (with perhaps some trade-off with respect to NO_x emissions) will benefit the areas in the Northeast that are sensitive to acid rain -- cannot be supported by available scientific information.

E. A Note on Dry Deposition

Gases and particles transported to a surface are removed by a variety of highly complex processes that are lumped together in a single parameter called "dry deposition." It is then assumed that the amount deposited is proportional to the atmospheric concentration. However, science has not yet reached the stage where it can measure dry deposition with any degree of accuracy. The dry ~~deposition~~ process is very much dependent on the nature of the surface (land-ocean, grass-crop-forest, wet-dry, etc.), meteorological parameters (wind speed, atmospheric stability, etc.), and plant physiological variables (stomata size, transpiration-respiration mode, etc.). Consequently, the magnitude of dry deposition has not been well quantified. Order of magnitude uncertainties are quite common, and they result in similar uncertainties in determining the depletion of the atmospheric substance downwind of its emission source. Thus, again, a source-receptor relationship cannot be reliably established at this time.

III. THE IMPORTANCE OF COPOLLUTANTS OTHER THAN SO_2 IN UNDERSTANDING ACID RAIN

As I have discussed above, SO_2 is one precursor of acid rain because it can be transformed into sulfuric acid (H_2SO_4) and sulfates. There are, however, other precursors of acid rain, including NO_x, and they too must be considered in devising a control strategy for acid rain.

The importance of nitric acid (HNO_3), an oxidation product of NO_x, to precipitation acidification is now well recognized. In a recent study, Galloway and Likens (1981)*/ determined that in the northeastern United States the contributions of sulfuric acid and nitric acid to the acidity of precipitation in summer are about 2:1 and in winter are about 1:1, respectively. (While this different seasonal behavior of sulfuric acid and nitric acid remains unexplained, it means that "effects" researchers who are concerned about the impact on aquatic systems of "pH shock" during snow melt should consider nitric acid on an equal basis with sulfuric acid.) A statistical analysis of records of precipitation composition for the Hubbard Brook Experimental Forest in the New England area for 1964-1979 showed that the importance of sulfuric acid in precipitation has decreased by about 30% relative to nitric acid, and that nitric acid has increased in importance by 50% relative to sulfuric acid.

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*/ Acid Precipitation: The Importance of Nitric Acid. J.N. Galloway and G. Likens. Atmospheric Environment 15:1081-1085, 1981.

Galloway and Likens also reviewed three other studies on the temporal trends of NO_3^- and $SO_4^=$ concentrations in precipitation (not in ambient aerosols) for Ithaca and Geneva (New York) for 1915-1975, for New York State for 1965-1979, and for Hubbard Brook Experimental Forest for 1964-1979. These studies found increases in the annual, volume-weighted concentration of nitrates, particularly during the last two decades. The trends of sulfate concentration in precipitation were more complex. For Ithaca and Geneva, the annual, volume-weighted sulfate concentration decreased sharply in the 1950's. Galloway and Likens attributed this decrease to a fuel shift from coal to natural gas in the Ithaca area. This suggests that local changes in SO_2 emissions can indeed influence sulfate wet deposition, and can even play a dominant role. Galloway and Likens concluded that long-term changes in the synoptic weather patterns were not a contributing factor to the long-term trends in precipitation composition since such changes in weather patterns would probably not cause both an increase in nitrate concentration and a decrease in sulfate concentration.

It should also be noted that no long-term trend in pH is discernible at Hubbard Brook, as shown in Figure 16. This suggests that a decrease in

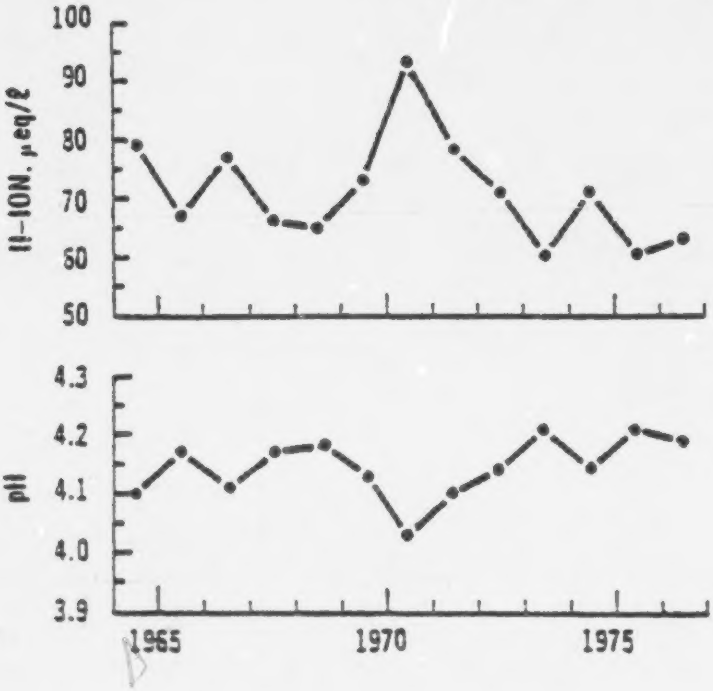

Figure 16.

Acidity of precipitation at Hubbard Brook (from P.F. Chester, Acid Rain, Emissions and Fisheries. IEEE Power Engineering Society Winter Meeting, Atlanta, Georgia, Feb. 3, 1981) sulfate might have been compensated for by an increase in nitrate. It seems more likely, however, that other parameters -- yet to be identified -- control the acidification of precipitation — i.e., govern the complex reactions that occur inside cloud droplets (referred to as "aqueous phase atmospheric chemistry").

It is also recognized that changes in the concentration of NO_x in the atmosphere are definitely not independent of changes in the concentration of SO_2 and sulfates. Cleveland and Graedel (1979),[*/] using a chemical kinetic model, showed that a reduction in nitric oxide (NO) causes a reduction in sulfates. Rodhe et al. (1980)[**/] cautioned that increases in NO_x emissions relative to SO_2 emissions may not be directly related to increases in the acidity of rain, because the increased amounts of NO_x may consume oxidants that would otherwise have contributed to the formation of sulfuric acid.

While this may sound confusing, the important fact is that these studies demonstrate that the presence and ratio of copollutants have an important impact on the transformation of SO_2 into sulfates. The rate-determining steps for this conversion are not necessarily the ambient concentration of SO_2, but rather in all likelihood are the presence and concentrations of other substances. In technical terms, this behavior may be described as follows: "the conversion of SO_2 molecules into sulfate is zero order with

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[*/] Photochemical Air Pollution in the Northeast United States. W.S. Cleveland and T.E. Graedel. Science 204:1273-1278, 1979.

[**/] Formation of Sulfuric and Nitric Acid in the Atmosphere During Long Range Transport. H. Rodhe, P. Crutzen and A. Vanderpol. WMO Symp. Long Range Transp. of Poll. and Its Relation to Gen. Circ. Incl. Stratospheric/Tropospheric Exchange Processes. Oct. 1979, Sofia, Bulgaria.

respect to SO_2." In more understandable language, this means that the transformation of SO_2 by physico-chemical processes into sulfates is independent of the ambient SO_2 concentration. It is obviously of fundamental importance when devising a control strategy for acid rain to know with certainty the order of reaction for the overall conversion of SO_2 into acidic material. If it is indeed "zero order," as field data seem to indicate, a control strategy for acid rain focused solely on reducing SO_2 emissions will be quite ineffective. Thus, a scientific control strategy for acid rain must, first, await the identification of what other substances control the conversion of SO_2 into acidic material that is brought to the ground and, then, include these other substances in an integrated program that is designed to minimize acid rain at designated sensitive areas.

The importance of copollutants or trace substances to the formation of acid rain can be illustrated by listing a few examples of potentially important aqueous phase reactions in the overall sulfur cycle.

- The solubility of SO_2 in cloud droplets or precipitation is strongly dependent on the pH of the droplet. A reduction of cloud pH from 5.6 to 4, a highly probable occurrence, makes SO_2 about 50 times less soluble in the droplet. This results in a slower oxidation rate, resulting in the SO_2 being transported further, and perhaps indicates that an oxidation-limiting mechanism for SO_2 exists in the atmosphere.
- Ambient ozone dissolved in cloud water can undergo a series of complex reactions resulting in the formation of hydroxyl radicals, $OH^{\cdot}$; $OH_2^{\cdot}$ and hydrogen peroxide (H_2O_2). These hydroxyl radicals in

turn influence the rate of oxidation of SO_2 to sulfate inside clouds. Hydrogen peroxide has already been identified as a very potent oxidizer of SO_2. While its presence in clouds and precipitation has been confirmed in several recent field studies, its origin is still subject to considerable scientific debate.

- Carbon particles (graphitic soot) are increasingly suspected of catalyzing the oxidation of SO_2. Furthermore, dissolved nitrogen dioxide (NO_2) has been shown to significantly increase the reactivity of SO_2 in the presence of graphitic soot. The reason for this complicated synergistic effect remains unknown.
- Dissolved organic matter may react with dissolved ozone and other radicals to form organic peroxides which may influence (positively or negatively) the oxidation of SO_2.
- Metal cations (iron, manganese, copper, titanium, vanadium, etc.) have a well demonstrated ability to catalyze the oxidation of dissolved SO_2.
- The synergistic effects of copollutants and NH_3 are extremely complex. The presence of NH_3 can raise the pH of the cloud droplet or precipitation. This would enhance auto-oxidation, metal cation oxidation and dissolved ozone oxidation. It would retard the oxidation potential of hydroxyl radicals (H_2O_2 and HNO_2) and copper ions. Carbon particle oxidation would not be affected.

Unfortunately, science has not to date been able to adequately define the effects of copollutants on aqueous oxidation rates of dissolved SO_2. Most aqueous phase laboratory studies done to date are inadequate for several reasons, including (1) insufficient description of experimental procedures, (2) improper reactor design, and (3) copollutant concentration levels orders of magnitude greater than possible ambient levels.

In the face of inadequate scientific knowledge of the role of copollutants relative to the chemical transformation of SO_2, it is *scientifically* unwarranted to adopt at this time a control strategy for acid rain that addresses only SO_2.

IV. APPARENT LACK OF IMPORTANCE OF AMBIENT SULFATE AEROSOL TO SULFATE WET DEPOSITION

It has been assumed during the past decade or so that ambient sulfate aerosol is mainly responsible for sulfate wet deposition. The mechanisms by which sulfate aerosol becomes incorporated into precipitation were thought to be in-cloud scavenging, called "rainout," and below-cloud scavenging, called "washout." There is reason to question the validity of this long-standing hypothesis that acid rain is predominantly caused by cloud and precipitation scavenging of ambient sulfate aerosol. Rather, it seems more likely that the dominant influence on acid rain is the in-cloud aqueous phase chemistry, described above, which can cause the nonlinear conversion of SO_2 in clouds into sulfates and sulfuric acid that can fall to the earth in precipitation.

Ambient sulfate aerosol represents only a small portion -- around 10 percent -- of the total sulfur burden of the atmosphere due to emissions, with higher percentages occurring during short-lived episodic events. The ambient sulfate aerosols that do exist in the air below the clouds are not, in significant measure, washed out by falling precipitation elements (rain and snow) due to the fine size of such aerosols; the sulfate aerosols have such a low inertia that they follow the air stream around the precipitation elements rather than collide with them. Furthermore, the in-cloud processes that are most important in causing sulfate to appear inside cloud droplets seem to be unrelated to ambient sulfate aerosol. These statements are supported by recent data from the Acid Precipitation Experiment ("APEX"), reported by Lazrus et al. (1981).[*] [illegible] that study, the acidity of clear air was measured before it overran a surface warm front anticipated to produce a large area of warm frontal precipitation. After it did overrun that front and precipitation began, the chemical composition of the precipitation at cloud level and at the surface was obtained. Strong acids that were present in the clear air could not account for the acidity observed in the cloud water, thus indicating that most of the sulfate produced in the cloud water was produced by the oxidation of SO_2 to sulfuric acid rather than being due to ambient sulfate. Further, below-cloud processes did not significantly affect the deposition of acids at the surface.

It thus appears, on the basis of preliminary investigations, that the importance of ambient sulfate aerosol to the acid rain phenomenon is considerably less than previously believed. Rather, the sulfate in acid rain appears to be largely attributable to the in-cloud transformation of SO_2 into sulfate. Because this process is nonlinear, poorly understood and greatly affected by the presence and concentration of other copollutants, science is not yet able to devise a strategy to control it. Moreover, because SO_2 has, in general, a shorter residence time in the atmosphere than does sulfate, local sources may have a greater effect upon acid rain than is commonly assumed.

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[*] This paper is cited on p. 7 above.

V. CONCLUSION

I have shown above that science cannot at this time be relied upon to aid in the design of an effective control strategy for acid rain. The major areas of uncertainty that must be resolved include: (1) the true nature of the apparently nonlinear relationship between upwind SO_2 and NO_x emissions and downwind depositions; (2) the ways in which the transformation of SO_2 and NO_x into sulfates and nitrates is influenced by such factors as meteorology, photochemical factors, changes in the ratio of SO_2/NO_x, and the presence and concentration of other copollutants (including ozone, hydrocarbons, etc.); (3) a better understanding of dry deposition; and (4) a significantly improved knowledge of atmospheric transport in general. Until science has a much better understanding of the processes involved in acid rain, there is simply no way to determine the extent, if any, to which a reduction in SO_2 or NO_x emissions in one part of the country will produce a reduction in acid rain in another part of the country.

In light of what I have said, I am surprised to observe that many persons appear to believe that the control strategy required by S. 1706 is adequately supported by science. A study relied upon by some as support for S. 1706 is the recent report of the National Academy of Science's National Research Council Committee on the Atmosphere and the Biosphere, entitled "Atmosphere-Biosphere Interactions: Toward a Better Understanding of the Ecological Consequences of Fossil Fuel Combustion." That report concludes (on page 181) that control of SO_2 and NO_x emissions "can significantly reduce the rate of deterioration of sensitive freshwater ecosystems," that it is desirable for such areas to have pH values no lower than 4.6-4.7, and that in the most seriously affected areas "this would mean a reduction of 50 percent in deposited hydrogen ions." Because I am not an expert on the ecological effects of acid rain, I am in no position to comment on whether the ecological damage caused by acid rain justifies the report's recommendation of a 50 percent reduction in deposited hydrogen ions for those areas most seriously affected. However, I have shown in this statement that it is wholly erroneous to assume, as S. 1706 appears to do, that a reduction in SO_2 emissions of 50 percent or 10 million tons will yield a reduction of 50 percent in deposited hydrogen ions. Both the emissions areas and the sensitive receptor areas addressed by S. 1706 are in the air shed in the eastern United States that exhibits the "superbowl" phenomenon, described above. As I have shown, the relationship in this region between upwind SO_2 emissions and downwind deposition is nonlinear. Source-receptor relationships cannot be established in this region, based on our current scientific knowledge. It is entirely conceivable, as I have shown by reference to the European experience, that a reduction in SO_2 emissions of as much as 50 percent within the area characterized as the "superbowl" might not have a measurable effect upon the amount of hydrogen ion deposition in the ecologically sensitive areas of the northeastern United States.

The ongoing, intensive scientific discussion on the overall transport and transformation of sulfur dioxide and the ultimate deposition of acidic materials upon sensitive areas leads me to conclude that science is not yet in a position to quantify in any way the acid rain phenomenon. Indeed, the regulator faces the problem of trying to design a control strategy without knowing, even qualitatively, how effective that strategy will be.

Testimony of
David G. Hawkins
Natural Resources Defense Council, Inc.

Mr. Chairman and members of the Committee, I appreciate the opportunity to testify on the important issue of acid rain. I would like to focus my remarks on the key features of the National Clean Air Coalition's acid rain control proposal and discuss the reasoning behind the specific features of that proposal.

The Coalition has proposed that Congress establish an emission reduction program for the eastern United States that would reduce sulfur dioxide emissions by ten million tons over the next ten years. Second, Congress should allocate this ten million ton reduction program among the electric utility companies operating in this region. Third, the utilities should be required to submit compliance programs to the federal government for approval. Fourth, each utility company should be allowed to achieve its share of the ten million ton reduction program by the most economically efficient means, including negotiating emissions reductions from other sulfur dioxide sources in the acid rain mitigation region. This last feature has been dubbed a "regional bubble."

These features of the Coalition program suggest a number of questions which you will probably want answered:

- Why ten million tons?
- Why focus on electric utilities?
- Why make it a federal program?

The Coalition selected a ten million ton reduction target after asking two questions about alternative reduction targets:

- How does the reduction target compare to the ultimate emission reduction we are likely to seek in order to protect our natural resources?
- How much does the reduction target cost?

Precise estimates of the ultimate level of control we will need to avoid further harm are not available now and will not be available for many years. However, the recent National Academy of Sciences report[a] on acid rain estimates that a 50 percent reduction in deposited hydrogen ions (the acidifying component of sulfur and nitrogen emissions) would be necessary to protect the most seriously affected areas.

Current eastern emissions of acidifying pollutants are roughly 23 million tons per year of sulfur dioxide and 13 million tons of nitrogen oxides. Given the acknowledged lack of precision in the National Academy's goal of a 50 percent reduction in hydrogen ions and the fact that sulfur and nitrogen compounds contribute differing amounts of hydrogen ions to the environment, the Coalition is not advocating a 50 percent reduction in the sum of these two pollutants, which would amount to an 18 million ton per year reduction.

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[a] "Atmospheric-Biosphere Interactions: Toward Better Understanding of the Ecological Consequences of Fossil Fuel Combustion" (1981), p. 181.

Our ten million ton reduction proposal amounts to a 43 percent reduction in eastern sulfur dioxide emissions if one completely ignores nitrogen oxides emissions. Depending on the weight given to nitrogen oxides emissions the Coalition's ten million ton proposal ranges from a 34 to 38 percent reduction in the combined total of eastern sulfur and nitrogen emissions.[b]

Thus, we believe that our ten million ton reduction program is less than what we will ultimately need to protect against acid rain damage, but is a good first step in reducing that damage. Lesser reductions in our view will do too little to reduce damage that is already occurring and will allow more damages to accumulate.

As I've said our choice of ten million tons was also influenced by assessing the costs of this and alternative programs. Initial cost studies that were available to us included a study done for the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Energy (DOE) by the consulting form, ICF.[c] This study analyzed the costs of alternative sulfur dioxide reduction strategies ranging from

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[b] Estimates are that sulfur dioxide may contribute two or more times the amount of hydrogen ions that nitrogen oxides do.

[c] "Alternative Strategies for Reducing Utility SO_2 and NO_x Emissions," Executive Summary, June, 1981.

2.7 to 7 million tons per year. The study calculated annualized cost increases in 1990 for these strategies ranging from $700 million to $2.2 billion per year, which amount to average eastern electricity rate increases of 0.6 to 1.8 percent.

Based on these results, the Coalition has asked ICF to analyze strategies that would reduce eastern sulfur dioxide emissions by ten million tons per year. We requested ICF to use the same assumptions used for the EPA/DOE study so that the results could be compared. While we have not received a final report from ICF, they have provided us with partial results of their analysis.

ICF projects that a ten million ton reduction accomplished by 1990 would result in a 1.9 percent increase in average eastern electricity rates in 1990 and the annualized costs of the program would be $2.4 billion. In the year 2000 eastern electricity rates would be 1.7 percent higher due to the program and annualized costs would be $3.4 billion.

The electricity rate increases from state to state will vary from the eastern average of 1.9 percent depending on how Congress allocates the shares of the reduction program between the various states. ICF has provided us with preliminary information on state rate increases under a program that would require reductions equivalent to controlling high-emitting plants to a level of 1.2 pounds of sulfur dioxide per million

BTU (30 day average). Rate changes range from a 0.5 percent rate reduction in the mid-Atlantic region to a 4.7 percent rate increase in the Ohio River Valley. The largest state rate changes that would occur under this formula would be from 6.5 to 8 percent increases in Ohio, Indiana, Kentucky, Tennessee and Missouri.

The states with the largest rate increases are among today's largest emitters. In 1990, even after these rate increases, these states would still enjoy rates less than those in the mid-Atlantic and New England states.

Based on these analyses the Coalition believes that a ten million ton reduction program can be accomplished at a moderate cost.

In short, the Coalition advocates a ten million ton reduction because it believes that is a minimum first step needed to protect our natural resources and that we can afford the costs of that step.

Our program focuses on utilities for a number of reasons. First, utilities emit 71 percent of eastern U.S. sulfur dioxide today. Second, without a reduction program their emissions will not decrease during the remainder of this century. Third, since emissions from many utilities are poorly controlled or not controlled at all today, they are a source of very cost-effective reductions. In the unusual instances where a particular plant would be required to employ very costly controls to get additional reductions, our proposal would allow the utility to trade emission reductions regionally to find the most cost-effective reduction. Thus, the program does not insist that the reductions occur at utilities. Rather, it assigns the emission reduction responsibility to utilities and gives them the flexibility to pursue those reductions at the least expensive sources.

The Coalition supports a federal program because the problem of acid rain is an interstate problem and a problem that needs prompt action.

Over the last decade the control of sulfur dioxide emissions has been the source of numerous disputes between the federal government and a number of states with high emissions. Given this history, we believe that an acid rain program which relied heavily on initiatives at the state level to develop solutions would result in additional years of controversy and delay.

One traditional argument against federal regulation is that state and local units of government may be able to find more efficient solutions to a problem because they are closer to the problem. We believe our proposal answers this concern by allowing institutions which are even closer to the problem--the utilities themselves--to select the most cost-effective solutions. Our proposal would specify how much must be done and let the utilities pursue the most cost-effective means of reaching that objective.

Our proposal would count on the states to take an active role in enforcing the specific emission reduction measures which are chosen by the utilities. We believe this division of responsibility between the states and the federal government holds the greatest promise for prompt development of an effective and efficient solution to an already serious interstate problem.

This concludes my prepared testimony and I would be happy to answer any questions you may have.

NATIONAL WILDLIFE FEDERATION
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STATEMENT OF DR. JAY D. HAIR
ON BEHALF OF THE NATIONAL WILDLIFE FEDERATION
AND
THE NATIONAL CLEAN AIR COALITION
AT HEARINGS ON ACID RAIN
BEFORE THE COMMITTEE ON ENVIRONMENT & PUBLIC WORKS
UNITED STATES SENATE
OCTOBER 29, 1981

Mr. Chairman and Members of the Committee:

Thank you for the opportunity to appear before this Committee on the subject of acid rain. I am Executive Vice-President of the National Wildlife Federation and appear here on behalf of the Federation's 4.6 million members and supporters (and our 53 state and territorial affiliates) as well as the National Clean Air Coalition, of which we are a member.

I am particularly pleased to respond to the Committee's invitation to provide our reactions to the proposed "Acid Deposition Control Act" (S. 1706), which has been co-sponsored by Senators Mitchell, Stafford, Chafee, Hart, and Moynihan of this Committee. I believe it is a bill which deserves the support of every member of this Committee. I will also provide some brief comments on the Dodd-Durenberger bill (S. 1718) and on the Moynihan bill (S. 1709).

I would like to set the stage for my comments on these bills by citing some of the factors that have persuaded us that acid rain is a growing threat to our environment and economy which must be dealt with on a vigorous and urgent basis.

For example, a report by the National Academy of Sciences (NAS) issued in early September ("Atmosphere-Biosphere Interactions: Toward a Better Understanding of the Ecological Consequences of Fossil Fuel Combustion"), highlighted the extreme seriousness of the acid rain problem in terms uncharacteristically firm for that normally staid and reserved body of scientists. The report concluded that: "The increased emissions of sulfur and nitrogen compounds from anthropogenic sources is the only plausible explanation for acid deposition" (p. 142), and that the evidence for the role of power plant emissions in the production of acid rain is "overwhelming" (p. 3).

Other striking conclusions from this report by our Nation's most prestigious body of scientists were that:

--at current rates of emission of sulfur and nitrogen oxides, the number of affected lakes can be expected to more than double by 1990, and to include larger and deeper lakes (p. 3);

--of the available options, only the control of SO_2 and NO_x emissions can significantly reduce the rate of deterioration of sensitive freshwater ecosystems (p. 181);

--control of SO_2 from new power plants alone would be insufficient to significantly reduce these acid rain impacts, so restrictions on older plants must be considered (p. 181);

--a significant reduction in the rate of deterioration of sensitive freshwater ecosystems would require a reduction in precipitation pH levels to "values no lower than 4.6 to 4.7, "which would mean a reduction of 50 percent in deposited hydrogen ions" in the most seriously affected areas (p. 181);

--continued emissions of sulfur and nitrogen oxides at current or accelerated rates, "in the face of clear evidence of serious hazard to human health and to the biosphere," will be "extremely risky" from the standpoint of long-term economic considerations as well as biosphere protection (p. 3);

--"the picture is disturbing enough to merit prompt tightening of restrictions on atmospheric emissions from fossil fuels and other large sources such as metal smelters and cement manufacture" (p. 7).

Other highlights of the NAS report have been entered into the the Congressional Record by Senator Mitchell. 127 Congressional Record. S10047-10049 (Sept. 18, 1981).

The issue of scientific certainty on the causes and effects of acid rain has been overplayed by those who wish to escape regulation. What they cannot escape is that there is a growing scientific consensus that enough is known to take firm initial steps to reduce the emissions that cause acid rain. The NAS report is evidence of that. So too is the fact that the Federation has already collected numerous signatures from noted acid rain scientists endorsing the view that "what is already known about [the acid rain] phenomenon amply justifies and requires immediate legislative steps to begin abating emissions of human generated acid rain precursors." A copy of the full acid rain position statement and a list of the 35 signators lined up to date is attached to my testimony as EXHIBIT 1, for inclusion in the record of this hearing.

The list of knowledgeable acid rain scientists who have endorsed this position statement covers many states, including Vermont, Tennessee, New Mexico, West Virginia, Texas, Colorado, and New York.

The existing and potential impacts of acid rain are real and profound and the trends are ominous.

Contrary to the contentions of those who wish to close their eyes to the problem, acid rain poses a serious threat to most of the eastern United States and to a growing number of states west of the Mississippi River. My staff has compiled a series of maps showing the distribution of low-pH rainfall and acid-sensitive soils and lakes in the 27 states east of the Mississippi River. These maps are based on recent studies of surface water alkalinity, bedrock geology, soil chemistry, soil type, and rainfall pH data collected from 1976-1980. By superimposing the maps of sensitive soils and surface waters on a map of U.S. Congressional Districts, those districts which may be most seriously impacted can be readily identified. Two of these maps are attached to my testimony as EXHIBITS 2 and 3.

Far from being a problem confined to the Adirondack region of New York, areas of the U. S. which may be profoundly affected by acid deposition include at least 15 eastern states and upwards of 100,000 miles of streams and 20,000 lakes.

My staff has also prepared a tabular representation of the acid rain sensitivities of the 27 eastern states in relation both to environmental impacts and materials damage. Our analysis showed that fully 15 of the eastern states must be regarded as extremely vulnerable to acid rain--including Maine, New York, Rhode Island, Vermont and West Virginia. We used data from current acid rain studies, from precipitation monitoring stations and from personal communications with scientific experts to rank these 27 states according to their vulnerability to fishery, soil, crop foliage, and masonry damage. Visibility and automobile paint damage were also considered--although these are measures of actual rather than potential impacts. A copy of our acid rain tabulation and the explanatory report ("Acid Rain Vulnerability of the 27 States East of the Mississippi River") is appended as EXHIBIT 4.

Finally, there appears to be mounting evidence of acid rain impacts and vulnerability in a growing number of western states. For example:

--Minnesota: receives a mean rainfall pH of 4.6 - 4.8, with individual storms as low as 3.6 (100 times more acidic than normal rainfall). Acid sensitive lakes are distributed throughout the central and northeastern parts of the State with damage occurring to 15 percent of the lakes and another 2,600 in immediate jeopardy. Beginning effects of acidification are being observed in lakes in the Boundary Waters Canoe Area in Voyageurs National Park in Minnesota. It has been estimated that acid rain impacts in Minnesota could reach $78 million a year for fishing and tourism, $40 million for corrosion of man-made materials, $65 million a year for reduced forest productivity, upwards of $400 to $600 million annually in lost soil fertility, and $40 million a year in human health costs.

--Colorado: rainfall pH in Boulder has declined from 5.43 to 4.63 (a 6-fold reduction) over a three-year period. Measurements taken during 1980 near Crested Butte reportedly showed a high acid level in small lakes and streams in the Elk Mountains.

--Wyoming: average precipitation pH recorded in Yellowstone National Park in 1980 was 5.2 (2½ times as acid as normal rain).

--Montana: average pH of precipitation in Glacier National Park is 4.9, with values as low as 4.4.

--Oregon: rainfall pH values as low as 4.1 (over 30 times more acid than normal) were recorded at the Schmidt Farm monitoring site in 1980.

--Arizona: pH values as low as 4.1 were recorded at the Cochise monitoring site in 1979. In 1980, the average pH recorded in Tombstone was 5.2.

--Nebraska: precipitation pH values as low as 4.3 were found in Lancaster County in 1979.

--New Mexico: precipitation pH values in the 3's and 4's have been reported in the Teseque watersheds in the Santa Fe National Forest.

--California: rainfall pH values as low as 2.9 were recorded in 1978. 1980 values as low as 3.9 were found in Yolo County.

--Idaho: the 1980-81 pH average at Craters of the Moon National Monument was 4.8.

--Washington: 24 of 68 lakes sampled in the Olympic Mountains and the Cascades had a pH of less than 6; 7 had a pH of less than 5.5 (all in the Alpine Lakes Wilderness, due east of Seattle). 70% of the rainfall monitored in Seattle ranged in pH from 5.2 to 4.2.

Excerpts of a recent Sports Illustrated article on acid rain, listing acid rain impacts of a number of vulnerable states were inserted in the Congressional Record by Senator Dodd--127 Cong. Rec. S11233-11235 (Oct. 7, 1981).

I'd also like to ask to have made part of the record (EXHIBITS 5 and and 6) two recently adopted resolutions on acid rain: first, a resolution entitled "Control of Acid Precipitation," adopted by the International Association of Fish and Wildlife Agencies (IAFWA) at their annual meeting in Albuquerque, New Mexico; and second, a resolution entitled "Environmental Effects of Acid Rain and Snow and Other Acid Deposition," adopted last week by the International Union for Conservation of Nature (IUCN) at its 15th General Assembly in New Zealand. IAFWA represents state and provincial fish and wildlife agencies throughout the United States, Canada, and Mexico. IUCN has 448 voting members in 109 countries, and is probably the most prestigious world-wide non-governmental body engaged in promoting scientifically based action for natural resource conservation.

We regard acid rain as one of the leading environmental issues of this decade. Thus, we are pleased to see these Senate bills which share a recognition that the time for control is now.

The National Wildlife Federation and the National Clean Air Coalition enthusiastically support the Mitchell et al. Bill (S.1706) because it represents a reasonable and effective approach for reducing acid rain in the eastern 31 states. The key elements of control legislation, reflected in S.1706, are that:

1) Congress should mandate a 10 million ton per year reduction in SO_2 emissions in the 31 Eastern states (those east of the Mississippi River, plus the 4 border states of Minnesota, Iowa, Missouri and Arkansas) to be achieved by 1990.

2) A federal formula should be devised for allocating the ten million ton reduction proportionately among utilities in the 31 states. Each state should be required to reduce its share of the 10 million figure, according to the ratio of utility emissions in excess of 1.2 lbs. of sulfur per million BTU's.

3) In achieving mandated reductions, sources should be able to consider and use a wide array of alternative methods--not limited to stack-scrubbing--for reducing their emissions in the most cost-effective manner.

We agree with the Mitchell et al. bill that Congress should mandate a 10-million-ton reduction in SO_2 emissions by 1990. The National Commission on Air Quality, when it issued its report last spring, found that a reduction totaling 7 million tons could be achieved at an increase of less than 2% in average utility rates in the eastern U.S. (about $2.2 billion per year). These costs are very reasonable when compared to the billions of dollars in damages annually inflicted on the eastern U.S. by acid rain.

Through the use of interstate trading or "bubbling" an additional 3-million-ton reduction in SO_2 could be achieved without significant additional cost. This total emission reduction goal of 10 million tons is extremely reasonable, and represents only about a third of the total SO_2 emissions in the U. S. It is the minimum reduction necessary to effectively deal with the acid rain problem. (The NAS report called for a 50% reduction in the most seriously affected areas; p. 181). Utility emissions account for approximately three-quarters of all SO_2 emissions in the eastern U.S. The National Academy of Sciences found that the role of power plants in the formation of acid rain is indisputable. Thus, we recommend that the Congress concentrate on the utilities responsible for achieving the necessary reduction in SO_2 emissions.

The Moynihan Bill (S. 1709) would achieve a reduction of only a little more than 6 million new tons of SO_2 emissions per year (by focussing on "major" stationary sources and "major" emitting powerplants, and by setting an emissions cap of 2 lbs. per million BTU's, rather than the 1.2 lb. cap in the Mitchell et al. bill). This is the principal reason we strongly prefer S. 1706 over S. 1709.

Congress should also specify a formula for allocating the 10 million ton reduction among the eastern 31 states. The National Clean Air Coalition originally suggested that this could be achieved by placing an emissions cap on utilities of 1.2 lbs. per million BTU's. These sources would then be required to submit a plan to EPA, detailing how they would meet their emission reduction obligations.

The Mitchell bill takes a somewhat different tact, which we also believe has merit. It is based on the premise that each states' share of the 10 million ton reduction should be allocated in proportion to its contribution to the total sulfur emissions in the region. This would be accomplished by requireing states to reduce their emissions in proportion to the amount of sulfur emitted by their utilities in excess of 1.2 lbs. per million BTU's.

We support the concept that states should be allowed to use any enforceable, cost-effective method for meeting the reduction obligations. As noted in the Mitchell et al. bill, these methods or techniques include state or regional bubbling, the use of least emissions dispatch, the early retirement of major stationary sources, investments in energy conservation, the trading of emission reduction requirements, and coal washing.

In reducing SO_2 emissions, the National Clean Air Coalition originally recommended a very strong federal role in requiring utilities to submit a plan directly to EPA designating how they would achieve the statutorily mandated reductions. Although the Mitchell et al. Bill places a significant burden on the states for ensuring compliance, we believe that a strong federal role is appropriate and desirable for the following reasons:

- Acid rain is an interstate problem. A strong federal government role is especially appropriate for dealing with interstate problems.
- The traditional role of the states in finding the most cost-effective means of reducing pollution would be replaced, under our original proposal, by the sources finding the most cost-effective reductions themselves.

obligations will interfere with interstate trading and decrease the substantial cost savings which flow from interstate bubbling.

- The midwestern states in which the largest emitters of SO_2 are located are unlikely to change their attitude and make a good faith effort to reduce the emissions from their states which are damaging, not their own state, but other states downwind. We frankly foresee substantial implementation and enforcement problems in the absence of federal standards and a strong federal role.

An acid-rain control program is only as effective as its enforcement. We are concerned because under the Mitchell _et al_. bill, state acid rain control programs are reviewed by EPA as part of the SIP process. History has proven that the federal enforcement of SIP's can be an elusive goal and subject to legal maneuvering designed to defeat the purposes of the mandated control program. The State of Indiana, for example, currently has no enforceable SO_2 requirements. Although Indiana's state implementation plan (SIP) was approved by EPA, the SO_2 requirements were invalidated by a state court. A Federal Court has recently ruled that the SO_2 requirements are therefore unenforceable. This is not an isolated incident. Similar problems have occurred, for instance in Illinois and Ohio. These three states are among the largest producers of SO_2 in the United States. We believe this issue needs to be further addressed.

We are, however, happy to see that the Mitchell-_et al_. bill contains a back-up program of federal controls which are immediately applicable if a state has not adopted appropriate control measures within a designated time-frame.

As a part of the overall program for mitigating acid rain, it is also critical that:

- Section 125 be retained, providing the authority to require use of locally derived coal to prevent serious economic dislocations;
- A limit be placed on utility stack heights;
- NO_x emissions from mobile sources be controlled.

We are adamantly opposed to any changes or relaxation of the NO_x auto emission standards. We believe that such attempts are reckless and can only exacerbate the already serious acid rain dilemma. In the end, they will cost the public much more than they will save.

- Consistent with the Administration's states' rights theme, states should be given broader authority to protect the quality of their air from interstate emissions.

Thus, we support the Dodd-Durenberger Bill (S. 1718), which we feel would complement the Mitchell Bill. S. 1718 would:

--broaden the interstate pollution provisions of the Clean Air Act, allowing affected states to seek clean-up of air pollution, to cover all sources of pollution emissions that are currently regulated by the States under the Act (instead of only emissions from "major" stationary sources);

--require that State Implementation Plans control emissions that would "interfere with" another State's ability to meet air quality standards or which would "endanger public health and welfare in any other State", instead of merely requiring control of emissions shown to actually "prevent" attainment or maintenance of air quality standards;

--spell out the factors that should be considered in evaluating a potential violation of the interstate pollution prohibition (including: total emissions from sources in each State; reasonable estimates of the contribution to one State's pollution of sources in another State; the meteorological conditions affecting the areas involved; and the comparative economic impact on both States of requiring additional pollution controls or of allowing the existing level of interstate pollution to continue);

--take the full burden of proof of an interstate pollution violation off of the State affected by the pollution and assign the EPA Administrator partial responsibility for establishing the facts of the case without bias or presumption on behalf of any State involved in a dispute; and

--extend the time in which the Administrator is required to act on a section 126 (interstate pollution) petition from 60 to 120 days, but give the petitioning State the right to file immediate suit at the end of this period to require the Administrator to act if he otherwise fails to do so (it would also authorize the court to award the petitioning State all litigation costs and a $100,000 penalty).

Our support for the Mitchell et al. bill is based upon the underlying premise that a significant reduction in the emissions of pollutants which cause acid rain will result in a significant reduction in the acidity of precipitation.

The theory underlying our approach to acid rain control is based upon simple economic logic. SO_2 emissions are primarily a byproduct of energy production. Just as the utilities must pay for their coal, pay for its transport, and pay for their labor, so too must they learn to pay for the proper disposal of their wastes, a cost no different from any of the other basic costs of production. Currently, many utilities are able to circumvent these costs by using our common resource--the air--as a free dumping ground for their waste. The costs remain, but rather than being borne by the utility and the direct consumer of the product, as we have seen--they are frequently borne by downwind receptors. Thus, in a very real sense, downwind receptors subsidize the utility rates of those upwind, and polluters have little economic incentive to control their emissions.

What the Mitchell et al. bill attempts to do is force utilities to begin internalizing the costs of these externalities, forcing the utilities and their direct consumers to pay the full (non-subsidized) cost of production and the product. Thus, providing utilities with economic incentive to reduce their emissions, and thus, their costs.

In closing, let me emphasize that we place a very high priority on mitigation of the acid rain dilemma.

We believe that further research will only confirm what is already known and well documented: Acid rain costs our nation billions of dollars each year. Lakes, rivers, and streams are irreparably damaged. The productivity of crops and forest lands may be diminished. Health care costs escalate, with millions of Americans paying the price of their health.

The causes of acid rain are known. The costs are real and profound. The trends are ominous. As the Mitchell et al., Moynihan and Dodd-Durenberger Bills all indicate, the time for legislative action is now.

EXHIBIT I

POSITION STATEMENT ON ACID DEPOSITION

The primary cause of acid precipitation in the eastern United States is believed to be man-made emissions of acid-forming materials. These materials--sulfur dioxide from burning sulfur-containing fuels, and nitrogen oxides from industrial and utility boilers and vehicular exhaust--can be chemically transformed in the atmosphere into acidic compounds. Acid precipitation precursors are carried by winds, often across great distances, before returning to Earth as rain or snow or being deposited in dry form.

Mounting evidence indicates that acid depostition can stress or kill aquatic species in waters unable to neutralize or "buffer" its acidity (as encountered, among other places, in the Adirondack and Appalachian regions, much of New England, Michigan, Wisconsin, Minnesota, and Oregon, and in parts of California and Colorado). In addition, acid precipitation mobilizes soil ions, which may lead to irreversible losses of soil nutrients and harmful conditions for soil and aquatic organisms. Acid deposition also destroys man-made materials and natural structures. For example, it accelerates metal corrosion, while exposure to sulfur compounds in the air causes blistering and scaling of painted and other treated surfaces and loss of surface cohesion of limestone and sandstone. The erosion of statues and stone structures by acid deposition is well documented.

Accordingly, although gaps remain in our complete understanding of acid deposition processes, and more research is needed to fill these voids, we, the undersigned scientists believe that what is already known about this phenomenon justifies and requires immediate legislative steps to begin abating emissions of human-generated acid rain precursors.

Signature ____________________ Date __________

Name ____________________

(Area code:) ____________________

Telephone No.

EXHIBIT I

LIST OF SCIENTISTS WHO HAVE SIGNED THE NWF ACID DEPOSITION STATEMENT

1.) Dr. John M. Melack
Dept. of Biological Sciences
University of California

2.) C. Ray Thompson
University of California
Statewide Air Pollution Research Center

3.) Dr. John E. Heasley
Systems Ecologist
Natural Resources Ecology Lab
Colorado State University

4.) Thomas W. Lester
Kansas State University

5.) Dr. G. Richard Marzolf
Division of Biology
Kansas State University

6.) Hugh T. Spencer, Sc.D.
Chemical and Environmental Engineering
University of Louisville
Louisville, KY.

7.) Robert D. Conkwright
MD. Geological Survey
Johns Hopkins University,
Baltimore, MD.

8.) James M. Hill
Mid-Atlantic Acid Rain Survey

9.) Arthur Kingle, Jr.
Mid-Atlantic Acid Rain Survey

10.) James Burtis, Jr.
Mid-Atlantic Acid Rain Survey

11.) Fred Davis
Mid-Atlantic Acid Rain Survey

12.) John F. Kundt
Mid-Atlantic Acid Rain Survey

13.) Steven Paul Aust
Mid-Atlantic Acid Rain Survey

14.) Maria-Victoria Chattey
Mid-Atlantic Acid Rain Survey

15.) Robert H. Beman
Mid-Atlantic Acid Rain Survey

16.) Alfred M. Beeton
Ann Arbor, Michigan

17.) Paul O. Fromm
Department of Physiology
Michigan State University

18.) Dr. Nathan M. Reiss
Dept. of Meteorology
& Physical Oceanography
Cook College
Rutgers, New Jersey

19.) Dr. Gerald E. Streit
Los Alamos Scientific Lab.
Los Alamos, New Mexico

20.) Dr. Carl Schofield
Dept. of Natural Resources
Cornell University
New York, New York

21.) Dr. G. R. Hendrey
Brookhaven National Lab
Upton, Long Island
New York

22.) Paul C. Katen, Ph.D.
Oregon State University
Dept. of Atmospheric Sciences

23.) Richard W. Boubel, Ph.D.
Dept. of Atmospheric Sciences
Oregon State University

24.) John McBain Hubbe
Dept. of Atmospheric Sciences
Oregon State University

25.) Dr. Raymond C. Mathews
Uplands Field Research Lab
Gatlenburg, Tennessee

26.) D. W. Holy
Environmental Engineering Division
TRW
Dallas, Texas

27.) Ronald D. Mathews
University of Texas at Austin
Austin, TEXAS

28.) John M. Skelly
Dept. of Plant Pathology and Physiology
Virginia Polytechnic Institute
Blacksburg, VA.

29.) Richard Klein
The University of Vermont
Department of Botany
Burlington, Vermont

30.) H. W. Vogelmann
The University of Vermont
Department of Botany
Burlington, Vermont

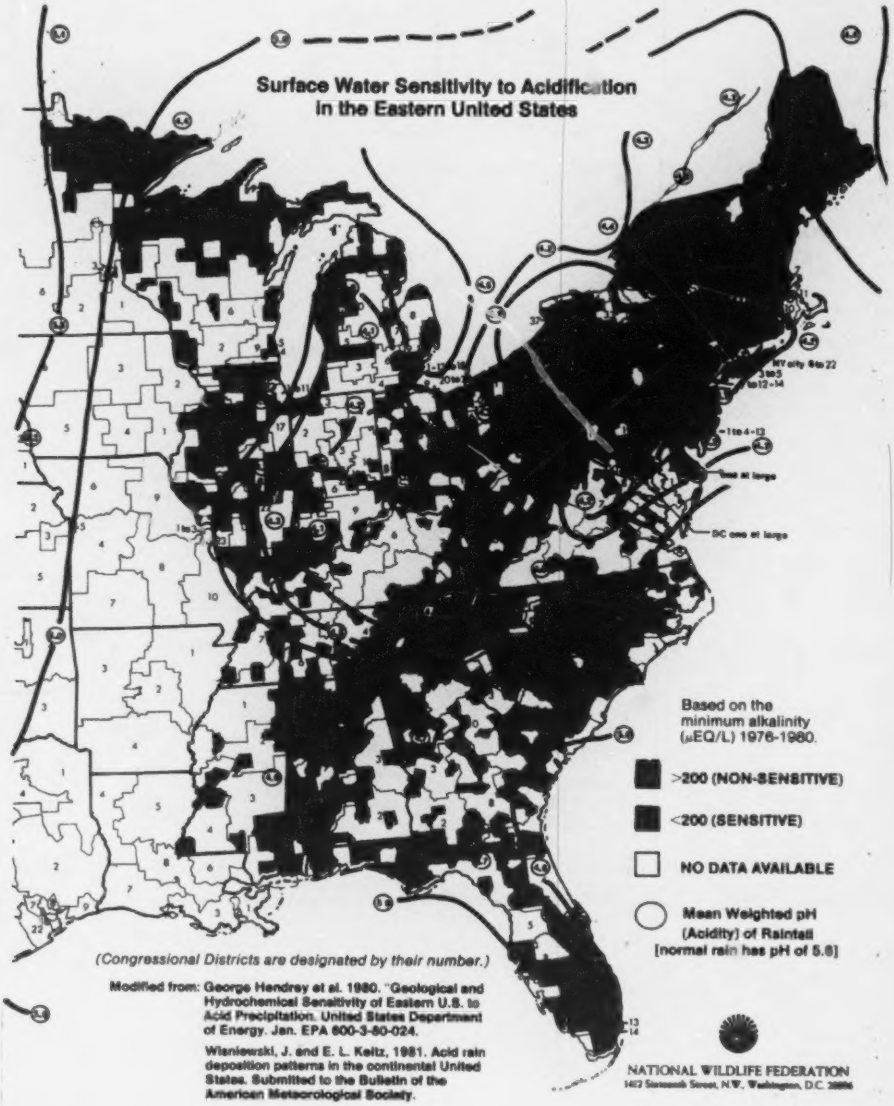
31.) Anthony C. Tomkowski, A.C.
Division of Forestry
West Virginia University

32.) James Galloway
Dept. of Environmental Sciences
Clark Hall
University of VA.
Charlottesville, VA.

33.) Dr. John J. Hassett
Professor Soil Chemistry
University of Illinois at Urbana

34.) Professor E.R. Altwicker, Ph.D.
Rensselaer Polytechnic Institute
Troy, New York

35.) D. R. Jackson
Battelle
Columbus Laboratories
Columbus, OHIO



Surface Water Sensitivity to Acidification in the Eastern United States

Based on the minimum alkalinity (μEQ/L) 1976-1980.

▨ >200 (NON-SENSITIVE)

■ <200 (SENSITIVE)

☐ NO DATA AVAILABLE

○ Mean Weighted pH (Acidity) of Rainfall [normal rain has pH of 5.6]

(Congressional Districts are designated by their number.)

Modified from: George Hendrey et al. 1980. "Geological and Hydrochemical Sensitivity of Eastern U.S. to Acid Precipitation. United States Department of Energy. Jan. EPA 600-3-80-024.

Wisniewski, J. and E. L. Keitz, 1981. Acid rain deposition patterns in the continental United States. Submitted to the Bulletin of the American Meteorological Society.

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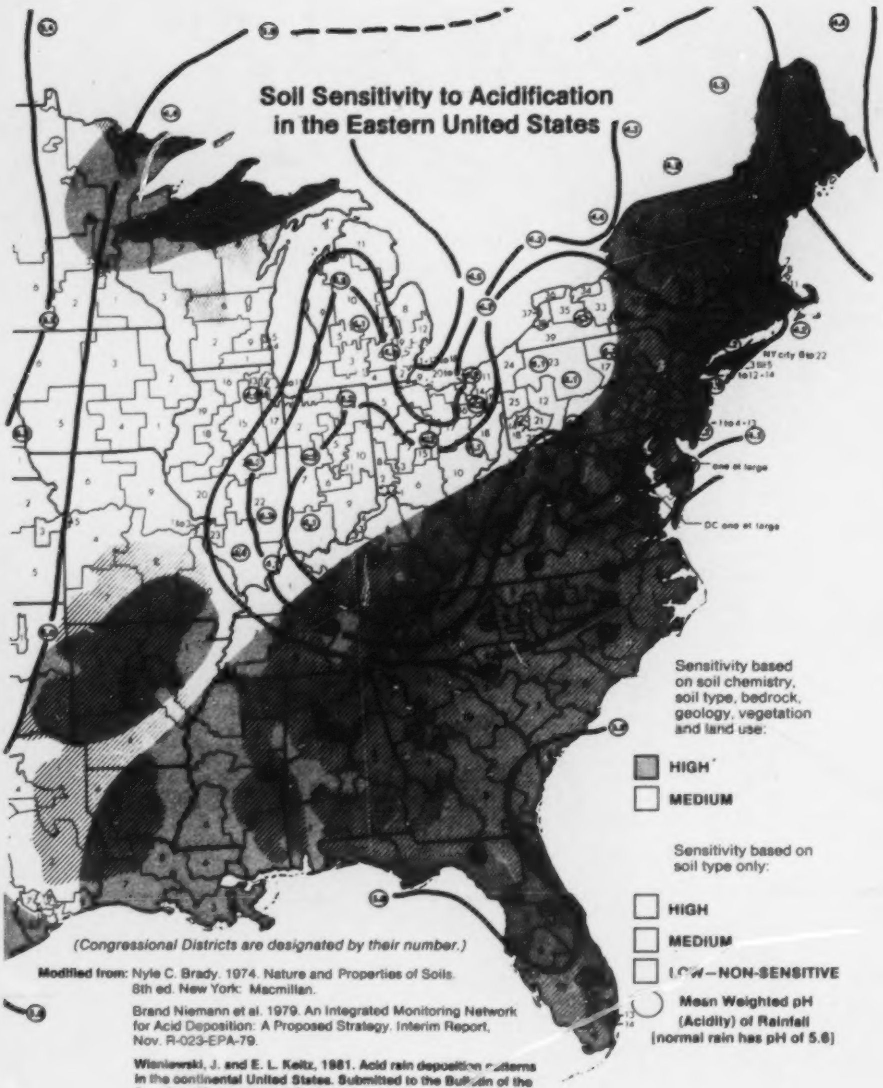

Soil Sensitivity to Acidification in the Eastern United States

NY city 6 to 22
1 to 4-13
one at large
DC one at large
Sensitivity based on soil chemistry, soil type, bedrock, geology, vegetation and land use:
HIGH
MEDIUM
Sensitivity based on soil type only:
HIGH
MEDIUM
LOW—NON-SENSITIVE
Mean Weighted pH (Acidity) of Rainfall [normal rain has pH of 5.6]

(Congressional Districts are designated by their number.)

Modified from: Nyle C. Brady. 1974. Nature and Properties of Soils. 8th ed. New York: Macmillan.

Brand Niemann et al. 1979. An Integrated Monitoring Network for Acid Deposition: A Proposed Strategy. Interim Report, Nov. R-023-EPA-79.

Wisniewski, J. and E. L. Keitz, 1981. Acid rain deposition patterns in the continental United States. Submitted to the Bulletin of the American Meteorological Society.

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ACID RAIN VULNERABILITY
OF THE
27 STATES EAST OF THE MISSISSIPPI RIVER

Acid rain is a problem of national significance in the United States. The scientific community has studied many of the impacts of acid rain and found a direct causal relationship between acid rain and the degradation of lakes, streams, soils, vegetation, and a variety of other adverse effects.

Using data from published acid rain studies, precipitation chemistry monitoring stations and from personal communications with scientific experts, the National Wildlife Federation (NWF) qualitatively assessed the overall acid rain vulnerability of the Eastern United States. NWF limited its evaluation to the twenty-seven states East of the Mississippi River where complete data was available. Several western states are, however, known to be highly sensitive to acid rain.

The 27 eastern states have been ranked according to their vulnerability to fishery, soil, crop foliage and masonry damage. Visibility impairment and automobile paint damage--measures of existing rather than potential impact--are also considered. A ranking of extreme (E), moderate (M) or low (L) vulnerability is assigned to each state based on factors specific to that state. NWF's summary table also provides a relative ranking of states determined by the sum of their acid rain sensitivities for each category.

In a related but separate exercise, NWF has prepared two maps illustrating the sensitivity of soils and surface waters to acidification for the same 27 states. These maps, which are based on current studies of surface water alkalinity, bedrock geology, soil chemistry, soil type and rainfall pH data collected from 1976-1980 portray the ability of soils and surface waters to buffer acidic inputs resulting from acid rain or dry acid deposition. By superimposing the maps of sensitive soils and surface waters on a map of U.S. Congressional districts, those districts which may be most seriously impacted are easily identified.

A superficial comparison of vulnerable areas indicated on both the maps and chart may reveal some apparent inconsistencies. This is attributable to the differential weighting and the incorporation of additional variables in the chart tabulations. Florida, for example, shows moderate to high soil sensitivity and some areas of sensitive surface waters according to both maps. Yet, when factors such as rainfall pH and bedrock geology are weighted in the evaluation, in addition to a relative ranking of sensitivity with respect to the other eastern states, Florida's soils and fisheries are classified as having low vulnerability to acid rain effects.

Despite these differences in approach, both studies demonstrate the pervasiveness and potential severity of the acid rain problem in the Eastern United States.

****

NWF considered multiple interactive factors in the preparation of the chart:

pH

pH is a numerical value which describes the acidity of a solution, and is commonly used to evaluate the degree of acidity of rainfall. The pH scale ranges from 1 to 14 with 7 as the neutral point and values less than 7 representing increasing degrees of acidity and values greater than 7 representing increasing degrees of alkalinity. The pH scale is logarthmic: for example, a pH value of 4 is 10 times more acidic than a value of 5 and 100 times more acidic than a value of 6. Acid Rain is defined as rainfall whose pH value is less than the pH of normal rain at 5.6.

Currently, there are precipitation chemistry monitoring stations throughout the United States which routinely record the pH of rainfall. NWF has received pH data from some of the major monitoring networks, such as NADP and MAPS and incorporated a pH range *(see footnotes 1-5) and average pH *(6) for each state into the chart. These values indicate the average acidity rainfall received by a state as well as the variability of the pH. It is important to note, however, that the pH values indicated in the chart may understate the severity of potential acid rain impacts. Many of the pH values used, reflect a limited period of monitoring and have been restricted to values obtained in the laboratory. Field pH data recorded at the monitoring sites generally tend to be lower (more acidic). In addition, pH measurements gathered separately by independent researchers, have revealed rain of even higher acidity (pH values in the two's and three's).

Fisheries Sensitivity

Acid rain adversely and irreversibly impacts fisheries by increasing the acidity of freshwater streams and lakes and by making toxic metals (i.e. aluminum, lead, mercury) more mobile. Both of these effects have been shown to damage fish and other aquatic life. The deaths of certain fish populations have been documented at increasing levels of acidity.

Although the most publicized acid rain-impacted fisheries in the U. S. are those of the Adirondack region in upstate New York, an examination of the factors which determine the sensitivity of water bodies to acidification reveals that the areas vulnerable to acid rain-induced fisheries damage are extensive. In evaluating the vulnerability of fisheries in each of the twenty-seven states, NWF considered studies which examined the following factors: surface water alkalinity *(7, 8), bedrock geology *(9) (both of which are indicators of the ability of the water to buffer acidic inputs), soil type *(10, 11), soil chemistry *(12) (both of which are indicators of the resiliency of the soil to buffer acidic inputs and, consequently, the leaching of toxic metals), and a mean weighted pH of rain *(14).

Surface water alkalinity was given the most weight in evaluating fisheries damage. NWF relied on two maps of surface water alkalinity in the Eastern U.S. The maps expressed minimum alkalinity of surface waters in micro-equivalents per liter (u eq/l)--with greater than 200 u eq/l ranked as low to non-sensitive, 100 to 200 u eq/l ranked as moderately sensitive and less than 100 u eq/l ranked as highly sensitive *(7,8). A bedrock geology map which indicated areas of high, medium and low sensitivity based on bedrock type was used to corroborate areas of sensitivity outlined on the surface water alkalinity maps *(9). Soil sensitivity maps based on soil type and other soil factors such as chemistry, vegetation, and land use were used to estimate the potential leaching of toxic metals into adjacent surface waters *(10,11,12). Finally, the mean weighted rainfall pH in each state was taken into account in determining a state's final fishery ranking *(13).

Soil Sensitivity

Acid rain may damage soils by increasing soil acidity, decreasing nutrient availability, mobilizing toxic metals, changing critical species composition such as decomposer microorganisms, and leaching important soil chemicals. Under persistent acid conditions in soils the net result of these changes can be a reduction in the biological activity and fertility of the soil.

In order to determine the vulnerability of each of the twenty-seven states to soil degradation by acid rain, NWF referred to studies of soil chemistry *(11, 12), soil type *(10), bedrock geology *(9), and mean weighted pH of rainfall *(13) for the eastern U.S.

Maps indicating areas of high, medium and low sensitivity of soils to acidification based on soil chemistry *(11, 12), soil type and bedrock geology *(9, 10), were considered equally in the determination of a final ranking for each state's soils. Data on the mean weighted pH of rainfall in each state was used in conjunction with these maps to justify a state's final vulnerability ranking *(13).

These factors, when considered in combination, reveal that 13 states have soils which are extremely vulnerable to acid rain effects, with 12 states possessing moderately vulnerable soils.

Crops

Acid rain may adversely effect crops by inhibiting plant productivity and crop yields. Laboratory studies have documented the rainfall acidity levels at which direct damage to plant foliage (in the form of lesions and necrosis) can occur. Such foliage injuries reduce the marketability of certain crops. In addition, because the period of most acidic rainfall coincides with the growing season of many crops, the agricultural industry of the East may be especially susceptible to significant economic impacts.

Agricultural crops such as alfalfa, tobacco, spinach, lettuce, carrots, potatoes and soybeans are vulnerable to damage at pH levels below 4.0 *(14,15,16,17,18,19,20), (40 times more acidic than normal rainfall). Using this general range below which damage may occur, NWF was able to roughly estimate the vulnerability of each state to crop foliage damage based on the occurrence of highly acidic rainfalls (pH data) recorded in each state *(1,2,3,4,5).

It was concluded that 23 states are vulnerable to crop foliage damage resulting from acid rain.

Masonry (i.e., limestone, marble) Sensitivity

Acid rain is one of many forms of pollutants which may act in conjunction with other oxidizing agents to accelerate the degradation of building materials. Masonry materials, such as limestone and marble, have been found to be especially vulnerable to attack. *(21,22, 23,24). Examples of irreversible damage to stone monuments and structures attributable to acid rain, have been reported in the United States as well as in Europe.

NWF estimated each state's vulnerability to masonry damage by applying mean-weighted annual pH data *(13) to a rough pH-based range of stone sensitivity *(22). According to these criteria, twenty-three states are classified as moderately vulnerable to acid rain-induced masonry damage.

Visibility Impairment

Visibility in the east has deteriorated considerably since the 1950's. This trend has been particularly noticeable in rural areas where decreased visibility is approaching that found in heavily polluted areas. Reduced visibility is closely related to sulfate and NO_x concentrations--precursors of acid precipitation. Specifically, sulfuric acid and various ammonium sulfate and NO_x aerosols can significantly affect visibility.

NWF's visibility impairment ratings are based on studies which determined the yearly average sulfate concentrations found in the U.S. during the mid 1970's *(25) and on NO_x concentrations found in the early seventies *(25). Based on these studies, it was estimated that 20 states had high visibility impairment, while 5 states had a moderate degree of impairment.

Automobile Paint Damage

There have been an increasing number of reports relating to acid spotting of automobile paints. Acid deposition damage to automobiles in the form of "polka-dotting" of auto finishes has become increasingly prevalent despite the improved durability of paint coatings over the past two decades.

This "polka-dotting" phenomenon occurs when sulfate particles and the resultant sulfurous and sulfuric acids accumulate on the flat surfaces of the hood, roof and decks of automobiles. After deposit on the paint surface, these chemicals can either etch the surface finish or leach pigments (such as lead chromate) from the paint surface.

Once the contaminant has entered the finish, the old finish has to be stripped down to the bare metal before refinishing--a very costly process.

NWF based the estimates of automobile paint damage occurring in each state, on actual reports of automobile paint damage received in each state *(26) as well as on sulfate/acid rain concentrations in each state *(27). It was found that Florida, New Jersey, New York, and Pennsylvania had the highest incidents of reported automobile paint damage due to acid rain last year.

* * *

Conclusions

The final tabulation of state-acid rain-vulnerability reveals that 15 states are extremely susceptible to the adverse impacts of acid rain, ten states are moderately vulnerable, one state demonstrates low vulnerability (and one state--Louisiana--cannot be evaluated based on insufficient information). This alarming conclusion, supplemented by the expansive areas revealed as sensitive on both acid rain maps in conjunction with reports of existing acid rain damage in many parts of the U.S., strongly refutes the contention that acid rain is a problem limited in the U.S. to the Adirondack region in upstate New York.

Based on these conclusions and its review of the most current acid rain studies, NWF advocates that legislative action be taken immediately to begin reducing the emissions of acid rain precursors--especially sulfur dioxide from major coal-fired electric generating stations in the Eastern United States. NWF believes that the acid rain problem should be addressed with a sense of urgency because much of the damage caused by acid rain is irreversible and current mitigation strategies, such as liming, have proven both ineffective and costly.

The National Academy of Sciences has recently issued a report which firmly supports NWF's conclusions and recommendations. Among the findings of the NAS report are the following:

- "[W]e find the circumstantial evidence for [the] role [of power-plant emissions in the production of acid rain] overwhelming..." (p. 3).
- "As a result [of acid deposition and consequent damage to aquatic ecosystems] several important species of fish and invertebrates have been eliminated over substantial parts of their natural ranges." (p. 133).
- "At current rates of emission of sulfur and nitrogen oxides, the number of affected lakes can be expected to more than double by 1990, and to include larger and deeper lakes..." (p. 3).

- "The control of emissions of sulfur and nitrogen oxides from fossil fuels is necessary to halt the acidification of sensitive aquatic ecosystems." (p. 132).
- "Of the options presently available only the control of emissions of sulfur and nitrogen oxides can significantly reduce the rate of deterioration of sensitive freshwater ecosystems... Control of SO_2 from new electrical generating plants alone would be insufficient to accomplish this, and thus restrictions on older plants must be considered." (p. 181).
- "Due to high costs and logistic difficulties, lime cannot be applied to the vast areas that are currently endangered by acidification." (p. 182).
- Any stimulus provided by deposited nitrogen and sulfur to terrestrial soils deficient in these elements "is expected to be short-lived..., and over the long term acid precipitation is likely to accelerate natural processes of soil leaching that lead to impoverishment in plant nutrients" (p. 3).
- "The Committee believes that continued emissions of sulfur and nitrogen oxides at current or accelerated rates, in the face of clear evidence of serious hazard to human health and to the biosphere, will be extremely risky from a long-term economic standpoint as well as from the standpoint of biosphere protection" (p. 3)*(28)

In the face of such clear and mounting evidence, it is difficult to ignore the acid rain problem. Instead, we must take action now to curtail the intensification and spread of acid rain before a growing catalogue of "vulnerable" states succumb to acid rain damage.

REFERENCES

1. MAP3S/RAINE Research Community. 1980. The MAP3S/RAINE Precipitation Chemistry Network: Statistical Overview for the Period 1976-1980. Submitted for Publication to Atmospheric Environment.

2. Environmental Protection Agency. 1981. ACID Computer Data Base (36RAW8). Statistical and Technical Analysis Branch, Environmental Monitoring Systems Laboratory, Research Triangle Park, North Carolina.

3. Personal communication with operators at monitoring stations.

4. National Atmospheric Deposition Program. NADP Data Report Precipitation Chemistry. Fourth Quarter 1979. Vol. 2, No. 4. Natural Resource Ecology Laboratory, Fort Collins, Colorado.

5. National Atmospheric Deposition Program. 1981. NADP Data Report Precipitation Chemistry. Second Quarter 1980. Vol. 3, No. 2, Natural Resource Ecology Laboratory, Fort Collins, Colorado.

6. U.S.-Canada Work Group 2. 1981. Phase II Working Report. Atmospheric Sciences and Analysis Report No. 2-15.

7. Hendrey, G.R., Galloway, J.N., Norton, S.A., Schofield, C.L., Shaffer, P.W., and Burns, D.A. 1980. Geological and Hydrochemical Sensitivity of the Eastern United States to Acidification. Appendix I. January. EPA 600/3-80-024.

8. Hendrey, G.R. 1981. Updated version of map appearing in: Geological and Hydrochemical Sensitivity of the Eastern United States to Acid Precipitation. United States Department of Energy. January. EPA 600/3-80-024.

9. Hendrey, G.R. et al. 1980. "Bedrock classification for Eastern United States showing sensitivity to acidification." In: United States-Canada Memorandum of Intent on Transboundary Air Pollution, Impact Assessment Interim Report, February 1981.

10. Brady, N.C. 1974. Nature and Properties of Soils. 8th Edition. New York: Macmillan.

11. Niemann, B.L., Root, J., Van Zwalenburg, N., Mahan, A.L. 1979. An Integrated Monitoring Network for Acid Deposition: A Proposed Strategy. Interim Report. Teknekron Research Inc., Energy and Environmental Systems Division, R-023-EPA-79.

12. McFee, William W. 1980. Sensitivity of Soil Regions to Acid Precipitation. EPA Report 600/3-80-013.

13. Wisniewski, J., and Keitz, E.L. 1981. Acid Rain Deposition Patterns in the Continental United States. Submitted to the *Bulletin of the American Meteorological Society*.

14. Jacobson, J.S. 1980. "Phytotoxicity of Acidic Precipitation." *Effects of Acid Precipitation on Terrestrial Ecosystems*. T.C. Hutchinson and M. Hans, eds.

15. Jacobson, J.S., and Van Leuken, P. 1977. Effects of Acidic Rain on Vegetation. Proceedings from Fourth International Clean Air Congress.

16. Longnecker, N.E., and Shriner, D.S. Assessment of the effects of acid precipitation on *Phaseolus vulgaris* L. "red kidney." Oak Ridge National Laboratory; Oak Ridge, Tennessee.

17. Haines, B., and Waide, J. 1980. "Predicting Potential Impacts of Acid Rain on Elemental Cycling in a Southern Appalachian Deciduous Forest at Coweeta." *Effects of Acid Precipitation on Terrestrial Ecosystems*. T.C. Hutchinson and M. Haras, eds.

18. Lee, J.J. and Weber, D.E. 1980. U.S. EPA 600/3-80-016, Corvallis Environmental Research Laboratory; Corvallis, Oregon.

19. Lee, J.J., Neely, G.E., Pemgan, S.C. 1980. U.S. EPA 600/3-80-016, Corvallis Environmental Research Laboratory; Corvallis, Oregon.

20. Wood, T., and Borman, E.H. 1974. "The effects of an artificial mist upon the growth of *Betula allegheniensis* B or H.," *Environ. Pollut.* 7:259.

21. Gauri, K.L. and Holden, G.C., Jr., 1981. "Pollutant effects on stone monuments." Environmental Science and Technology, Vol. 15, No. 4.

22. Personal communication with Dr. K. Lal Gauri, University of Louisville; Louisville, Kentucky.

23. Gauri, K.L., and Gwinn, J.A. 1981. "SO_2 and NO_2 Attack on Marble." National Bureau of Standards, Proceedings from Second International Conference on the Durability of Building Materials and Components, September 14-16.

24. Haynie, F.H. 1981. "Erosion of Marble." National Bureau of Standards, Proceedings from Second International Conference on the Durability of Building Materials and Components, September 14-16.

25. Environmental Protection Agency. 1975. Visibility Study. Office of Air, Noise and Radiation. National Technical Information Service; Springfield, Virginia. EPA 600/3-78-075.

26. Office of Technology Assessment. 1979. Yearly Average Sulfate Concentration during the mid 1970's. In: Health Effects of Fossil Fuel Burning. Richard Wilson, 1980.

27. Actual reports from auto dealerships and auto refinishing shops.

28. National Research Council. 1981. Atmosphere-Biosphere Interactions: Toward a Better Understanding of the Ecological Consequences of Fossil Fuel Combustion. Committee on the Atmosphere and Biosphere, Board on Agriculture and Renewable Resources. Washington, D.C.: National Academy of Sciences.

EVALUATION OF EASTERN STATES' VULNERABILITY TO EFFECTS OF ACID RAIN

State	pH RANGE OF RAINFALL	AVERAGE pH OF RAINFALL	FISHERIES	SOIL	CROP FOLIAGE	MASONRY (MARBLE, LIMESTONE)	OVERALL RANKING	VISIBILITY IMPAIRMENT	AUTOMOBI PAINT DAMAGE
Alabama	3.7 - ...	4.6	M	M	V	M	M	E	S
Connecticut	3.6 - ...	4.4	E	E	V	M	E	E	S
Delaware	3.5 - 5.0	4.4	M	M	V	M	M	E	M
Florida	4.2 - 6.1	4.7	S	S	NV	S	S	M	E
Georgia	4.1 - 6.3	4.6	M	M	NV	S	M	M	S
Illinois	3.8 - 6.7	4.3	S	S	V	M	M	E	M
Indiana	3.8 - ...	4.3	S	M	V	M	M	E	M
Kentucky	3.7 - ...	4.4	M	E	V	M	E	E	M
Louisiana	XX	4.6	XX	M	XX	S	XX	E	S
Maine	3.4 - 6.9	4.4	E	E	V	M	E	S	S
Maryland	3.7 - ...	4.3	M	M	V	M	M	E	S
Massachusetts	3.5 - 5.7	4.1	E	E	V	M	E	E	M
Michigan	3.8 - 6.1	4.4	E	E	V	M	E	E	M
Mississippi	4.2 - 5.3	4.6	M	M	NV	S	M	E	S
New Hampshire	3.7 - 6.2	4.3	E	E	V	M	E	S	M
New Jersey	3.5 - ...	4.3	E	M	V	M	E	E	E
New York	3.4 - 5.1	4.2	E	E	V	M	E	E	E
North Carolina	3.3 - 6.9	4.4	E	E	V	M	E	M	M
Ohio	3.6 - 5.1	4.2	S	M	V	M	M	E	M
Pennsylvania	3.5 - 5.9	4.2	E	E	V	M	E	E	E
Rhode Island	3.5 - ...	4.4	E	E	V	M	E	E	M
South Carolina	3.2 - 4.7	4.6	E	M	V	M	E	M	S
Tennessee	3.5 - ...	4.4	M	M	V	M	M	E	S
Vermont	3.5 - ...	4.3	E	E	V	M	E	M	M
Virginia	3.1 - 5.1	4.4	M	M	V	M	M	E	M
West Virginia	3.8 - 6.3	4.3	M	E	V	M	E	E	M
Wisconsin	3.8 - 6.1	4.5	E	E	V	M	E	E	M

E--Extremely vulnerable to acid rain effects	V—Vulnerable to acid rain effects
M--Moderately vulnerable to acid rain effects	NV—Not vulnerable to acid rain effects
S--Slightly vulnerable to acid rain effects	XX—Insufficient data

EXHIBIT 5

Adopted by the
International Association of
Fish and Wildlife Agencies
at its
71st Annual Convention
Albuquerque, New Mexico, September 16, 1981

Resolution No. 12

Control Of Acid Precipitation

WHEREAS, sulphur and nitrogen oxide emissions are causing acid precipitation to occur over large areas of eastern and midwestern North America, posing a threat to fish, wildlife, and their habitats in ecosystems with little geological buffering capacity; and

WHEREAS, recent information indicates that acid precipitation also may be damaging fish, wildlife, and their habitat areas of western North America; and

WHEREAS, the United States and Canada have, in recognition of the international implications of the problem, initiated negotiations on an arrangement for control of transboundary air pollution, and

WHEREAS, these discussions have not yet produced agreement on specific measures to ameliorate the situation, and

WHEREAS, the U.S. Administration has established principles for reauthorization of the Clean Air Act which conceiveably might result in increased acid precipitation, and

WHEREAS, reduction in sulphur dioxide emissions from fossil fuel-fired power plants is regarded as probably the most cost-effective first step in reduction of acid precipitation; and

WHEREAS, immediate steps are required to reduce acid precipitation and thereby prevent additional damage to fish and wildlife resources and their habitat;

NOW, THEREFORE, BE IT RESOLVED that the International Association of Fish and Wildlife Agencies urges the U.S. and Canadian Goverments to take the following actions;

1. Retain and vigorously enforce existing Clean Air Act limitations on emissions of sulphur and nitrogen oxides;
2. Enact new legal authority to substantially reduce sulphur dioxide emissions in North America by 1990;
3. Maintain comprehensive, long-term research and monitoring programs to better define, quantify, and solve problems caused by the impact of acid precipitation on fish, wildlife, and their habitat.
4. Support and implement the Memorandum of Intent between Canada and United States for development of cooperative measures to combat transboundary air pollution.

INTERNATIONAL ASSOCIATION OF FISH AND WILDLIFE AGENCIES, 1412 16th St., NW, Washington, DC 20036 (202, 232-1652)
(Association of each state or territory of United States, each Province of Canada, the Commonwealth of Puerto Rico, the United States Government, the Dominion Government of Canada, and each Government of a country located in the Western Hemisphere as well as individual Associate members whose principal objective is conservation, protection and management of wildlife and related natural resources.)

UNION INTERNATIONALE POUR LA CONSERVATION
DE LA NATURE ET DE SES RESSOURCES

INTERNATIONAL UNION FOR CONSERVATION
OF NATURE AND NATURAL RESOURCES

15th GENERAL ASSEMBLY NEW ZEALAND 11-23 OCTOBER 1981

EXHIBIT 6

XVI. ENVIRONMENTAL EFFECTS OF ACID RAIN AND SNOW AND OTHER ACID DEPOSITION

RECALLING the principles of the Declaration on the Human Environment, 1972, and Resolution No.4 of the 14th Session of the IUCN General Assembly, Ashkhabad, USSR, 1978 on environmental effects of sulphur dioxide pollution;

RECOGNISING that the Convention on Long Range Transboundary Air Pollution, Geneva, 1979 (ECE Convention) was signed by 35 nations in November 1979;

RECOGNISING that since 1978 additional scientific documentation has shown that emissions of sulphur dioxide and nitrous oxides in one region have devastating effects on many ecosystems and species in other regions;

OBSERVING that the acid deposition problem has been severe in North America and in Europe, where many aquatic ecosystems have been stripped of life and damage has occurred to forest areas, agricultural crops, and man-made structures of historical value, as well as causing possible hazards to human health;

NOTING that

- long range transboundary air pollution is an increasingly urgent problem demanding active preventive measures both nationally and internationally;
- significant advances have been made in technologies to combat air pollution at the source; and
- problems of long range transboundary emitted pollutants and the generation of secondary products are aggravated by the use of high stacks;

The General Assembly of IUCN, at its 15th Session in Christchurch, New Zealand, 11-23 October 1981:

URGES that

(a) all nations concerned ratify the ECE Convention on Long Range Transboundary Air Pollution as soon as possible and no later than the 1982 meeting of the Interim Executive Body of this Convention.

(b) nations outside the ECE region join in other international agreements to control air pollution as rapidly as possible through vigorous efforts to curtail sulphur and nitrogen oxide emissions;

(c) governments implement actively the obligations of the ECE Convention and other agreements to reduce the total industrial and domestic emissions of sulphur dioxide and nitrous oxides using the best available technology for such pollution reduction; and

(d) governments use their best endeavours to ensure that no further increases of sulphur and nitrous oxides emission levels are allowed.

0028A
15.10.81

ENVIRONMENTAL DEFENSE FUND

MEMORANDUM

TO: Concerned Officials, Organizations and Individuals

FROM: William Y. Brown, Scientist, Wildlife Program
Michael J. Bean, Attorney, Wildlife Program

SUBJECT: ACID RAIN AND WILDLIFE CONSERVATION

DATE: August 10, 1981

Enclosed is an EDF paper entitled "Acid Rain and Wildlife Conservation." The paper distills a mass of information compiled jointly by the United States and Canada in preparation for the negotiation of an international agreement on transboundary air pollution. Although prepared for internal governmental use, these data were recently made available to the public. Several additional studies, including in particular work done on damage to forests, are also included in the EDF paper.

The observations summarized in this paper are sobering. Major areas of eastern North America, and perhaps the West, are threatened with massive loss of life forms because of acid rain. Although continuing, intensive research on the problem is essential, failure to take immediate steps to curtail the responsible pollutants, sulphur dioxide in particular, would demonstrate a reckless attitude of our society toward living resources.

We urge you to read the paper carefully and to do what you can to solve the problem. Two fundamental steps are urgent:

- The Congress must not weaken the limits on sulphur and nitrogen oxide pollution currently required under the Clean Air Act.
- A new law should be enacted to substantially reduce sulphur dioxide emissions in the eastern United States. The National Clean Air Coalition is working on this bill and it needs your support.

Please contact us if we can be of further assistance.

1525 18th Street, N.W. Washington, DC 20036 ☎ 202-833-1484
OFFICES IN: NEW YORK, NY (NATIONAL HEADQUARTERS); WASHINGTON, DC; BERKELEY, CA; DENVER, CO

ACID RAIN AND WILDLIFE CONSERVATION

Prepared by Dr. William Y. Brown

Environmental Defense Fund

August 1981

> Acid deposition is currently being observed in most of eastern North America. Within this half-continent are large areas in which the surface soil material and bedrock types have little buffering capacity for acid inputs and are identified as "potentially sensitive." These areas include some of the most unique, unspoiled and biologically productive environments in North America. The potential is high for environmental degradation from the deposition of acid and other pollutants. (U.S.-Canada Work Group on Impact Assessment of Transboundary Air Pollution, Interim Report, January 15, 1981.)

THE CAUSES

Acid rain is caused principally by pollution of the air with sulphur oxides and nitrogen oxides. Most sulphur oxides come from the smoke of coal-fired power plants and ore smelters. These power plants, plus car and truck exhaust, add nitrogen oxides to the air. In atmospheric water, sulphuric acid and nitric acid are formed. These acids fall with rain and snow, then flow to streams and lakes. Precipitation in large areas of North America is forty times more acid than normal. Sometimes combined with acids formed on the ground by gaseous and solid pollution, this acid rain is destroying wildlife in poorly buffered areas over much of the eastern United States and Canada.[1,2]

THE MECHANISMS

Acid rain destroys wildlife primarily in three ways. First, acid rain directly inhibits reproduction in many species.[2,3,4] Second, acid rain can release toxic metals (aluminum, manganese, iron) which kill animal and plant life.[5,6,7,8,9] Third, acid rain can discharge from ecosystems other metals which are essential to many plants and animals (calcium and magnesium).[8,9]

THE DESTRUCTION OF WILDLIFE

Freshwater Lakes and Streams

Acid rain can dramatically alter the kinds and diversity of animals and plants inhabiting lakes and streams. Many lakes have been stripped of most native life altogether.

disruption of microorganisms

Field and laboratory studies in Scandinavia and North America indicate that bacterial diversity decreases in acidified water, accompanied by an increase in fungi, decrease in community respiration, and possible inhibition of the Nitrogen Cycle.[2,10]

degradation of plankton

Plankton communities in lakes are sensitive to rising acid concentration. Generally one or two species of resistant algae become abundant while other native species diminish and may be lost.[11,12] Overall, species diversity drops.[13,14,15] The dominant algae in acid lakes, a group called dinoflagellates, cannot readily be eaten by invertebrate animals in the plankton.[2,11]

invasion of Sphagnum moss

When lakes become acid, species of larger plants may be replaced by Sphagnum mosses. Moss invasion has been documented in Sweden, Canada, and New York State.[16,17,18,19] Sphagnum moss forms extensive, dense beds. In New York State, growth of moss has been accompanied by proliferation of acid tolerant algae, which has completely covered larger plants in some areas and blocked the capture of sunlight.[19]

disappearance of molluscs and crustaceans

Molluscs and crustaceans cannot live in acid waters. Molluscs are generally restricted to water with pH greater than 5.8 to 6.0--less acidic than many lakes affected by acid rain.[20,21,22] Many crustaceans are similarly sensitive.[23] The need of these animals for calcium, and its depletion from waters turned acid, may be responsible.[2]

failure of reproduction in amphibians

Many species of frogs, toads and salamanders breed in temporary pools of meltwater formed in the spring. These pools are often very acid. Embryonic mortality and deformity is great in certain salamanders at pH less than 6.0. Yet the average breeding pool for these same species is 32 times more acid.[3,24] Particularly sensitive species of amphibians include:[25]

Wood frog (*Rana sylvatica*)
American toad (*Bufo americanus*)
Northern spring peeper (*Hyla crucifer*)
Chorus frog (*Pseudacris triseriata*)
Yellow-spotted salamander (*Ambystoma maculatum*)
Blue-spotted salamander (*Ambystoma laterale*)
Tremblays salamander (*Ambystoma tremblayi*)

It is inevitable that amphibian species such as these will suffer severe decreases and will become locally extinct. Reduction in the biomass of amphibians may have far-reaching effects in both aquatic and terrestrial ecosystems, because salamanders and frogs are important prey for birds and mammals.[2]

fish loss

High acid concentration can inhibit larval development of fish and promote aluminum and mercury concentrations to toxic levels.[2,5,7,26-30] Massive kills have been observed for Atlantic salmon[31] and brown trout[32] in Europe and for pumpkinseeds, during spring snow melt, in North America.[33] However, less dramatic increases in mortality and drops in reproduction are more significant over the long term, eliminating many species from significant areas of their range:

- brook trout no longer can survive in at least 180 acidified Adirondack ponds where they formerly lived.[34]

- nearly half of the Aidrondack lakes may be acidified and devoid of fish--10 times more than 50 years ago.[35]

- fish have disappeared from many lakes in Ontario, Canada. Consider Lumsden Lake (one of 68 case studies):[33]

  1950s: 8 species of fish present.
  1960: last report of yellow perch and burbot.
  1960-65: sport fishery fails (pH 6.8 in September of 1961).
  1967: last capture of lake trout.
  1968: white sucker suddenly rare.
  1969: last capture of trout perch, lake herring and white sucker.
  1970: only lake chub present.
  1971: lake chub very rare (pH 4.4 in August of 1971).

  Thousands of lakes in Ontario and Quebec, many of them prime sport fisheries for U.S. and Canadian citizens, may be similarly lost if acid rain continues at present rates.[2]

- In Nova Scotia, acidification threatens 30% of the Atlantic salmon populations. Salmon reproduction has ceased in nine rivers where the fish once lived. Canada may be following in the footsteps of Norway, where acid rain has devastated salmoid fish.[36]

Fish populations in lakes and rivers generally are genetically distinct, being locally adapted. Elimination of a population is therefore not reversible by restocking. Furthermore, replacement stocks will not survive if acid rain is not abated, nor will they survive with lower acid concentrations if essential elements have been expelled from the ecosystem by former high acidity.[2]

decline of birds and mammals

Birds and mammals which depend on acid-sensitive animals and plants for food can be expected to decline when feeding lakes and streams become acidified. Fish-eating birds have disappeared from acid lakes in Sweden.[14,37] In North America, the Common Loon has declined in the Adirondacks over the last 15 years, paralleling the decline in fish populations as well as increased human disturbance.[38,39] The following birds and mammals are considered particularly susceptible to acid rain in North America and should be monitored closely:

Birds and Mammals Susceptible to Acid Rain [25]

Common Loon
(*Gavia immer*)

Common merganser
(*Mergus merganser*)

Hooded merganser
(*Mergus cucullatus*)

Red-breasted merganser
(*Mergus serrator*)

Great blue heron
(*Ardea herodias*)

Belted kingfisher
(*Megaceryle alcyon*)

Common goldeneye
(*Bucephalus clangula*)

Ring-necked duck
(*Aythya collaris*)

Black Duck
(*Anas rubripes*)

Green-winged teal
(*Anas carolinensis*)

Mallard
(*Anas platyrhynchos*)

Northern pintail
(*Anas acuta*)

American widgeon
(*Anas americana*)

American mink
(*Mustela vison*)

River otter
(*Lutra canadensis*)

Muskrat
(*Ondatra zibethicus*)

Forests

Beech and spruce forests in West Germany provide the only long-term information concerning effects of acid rain on forests.[8]. In these forests, already acidic rain is made two to four times more acid by sulphur dioxide and particulates. The acid is releasing aluminum salts in the soil, killing rootlets. The beech forest is considered to be doomed and the spruce forest unlikely to survive.

These studied West German forests are grown on sensitive, unbuffered soil. No industry is in the forest area, although the Essen-Dusseldorf Industrial Area lies 130-150 km to the west. No study has demonstrated such damage to forests in North America. However, many forest ecosystems should be considered at risk and monitored carefully. These include such unique ecosystems as the Boundary Waters Canoe Area Wilderness of Northern Minnesota,[40] the Great Smoky Mountains National Park in Tennessee and North Carolina,[41] the Adirondack Mountains in New York,[42] and the Kejimkujik National Park in Nova Scotia.[2]

THE SOLUTION TO THE PROBLEM

Acid rain will abate only with reduction in the amount of sulphur and nitrogen oxides put into the air by coal-fired power plants, smelters, refineries, cars, trucks, and other sources. A major positive and feasible step would be reduction in the amount of sulphur dioxide emissions by power plants. The National Commission on Air Quality has estimated that a seven million ton reduction in annual sulphur dioxide emissions by eastern utilities can be achieved by 1990 with an average increase of less than two percent in eastern utility bills. The National Clean Air Coalition is investigating the additional cost of a reduction totaling ten millions tons. Because a reduction of seven to ten million tons of sulphur dioxide constitutes some 40% to 57% of total emissions in the East, the abatement of acid rain would be substantial.

To stop the destruction of wildlife by acid rain, concerned citizens, organizations, government agencies and elected officals should:

- support those existing limitations on emissions of sulphur and nitrogen oxides which have been set under the Clean Air Act. Many efforts are now underway to weaken the Clean Air Act this autumn, and your help is needed to keep the law intact.
- support the efforts of the National Clean Air Coalition to have new legal authority enacted to substantially reduce sulphur dioxide emissions by 1990.

REFERENCES

1. Liken, G.E., R.F. Wright, J.N. Galloway, and T.J. Butler. 1979. Sci. Amer. 241:43-51.

2. U.S.-Canada Work Group on Impact Assessment of Transboundary Air pollution, Interim Report, January 15, 1981. [This document is the principal source of information referenced here in this paper.]

3. Pough, F.H., and R.E. Wilson. 1977. Water Air Soil Pollution 7:307-316.

4. Fromm, P.O. 1980. Environ. Biol. Fishes 5:79-93.

5. Cronan, C.S., and C.L. Schofield. 1979. Science 204:304-306.

6. Muniz, I.P., and H. Leivestad. 1980. In D. Drablos and A. Tollan (eds.), Ecol. Impact of Acid Precip., Proc. Int. Conf., Sandefjord, Norway, March 11-14, 1980. pp. 84-92 and 320-321.

7. Schofield, C.L., and J. Trojnar. 1979. In T. Toribara, M. Miller, and P. Morrow (eds.), Polluted Rain, Plenium Press, N.Y. pp. 347-366.

8. Tomlinson, C.H. 1981. Acid Rain and the Forest--The Effect of Aluminum and the German Experience. Research Memorandum Project No. 74-7124-13. DOMTAR Research Center. Senneville, Quebec.

9. Gaspar, D.C. 1981. Acid Rain and Snow, and Trout in West Virginia. W. Va. Dept. of Natural Res. Unpublished.

10. Traaen, T.S. 1980. In Drablos and Tollan, op. cit., pp. 340-341.

11. Dickson, W., E. Hornstrom, C. Elkstrom, and B. Almer. 1975. Info. from Soetvattens-Laboratorie, Drottningholm, Sweden, Paper No. 7, 140 pp.

12. Yan, N.D.. 1979. Water Air Soil Pollution 11:43-55.

13. Kwiatkowski, R.E., and J.C. Roff. 1976. Can. J. Bot. 54:2546-2561.

14. Almer, B., W. Dickson, C. Ekstrom, and E. Hornstrom. 1978. In J.O. Nriagu (ed.), Sulfur in the Environment: Part II Ecological Impacts, John Wiley and Sons, New York, pp. 271-312.

15 Leivestad, H., G. Hendrey, I.P. Muniz, and E. Snekvik. 1976. In F.H. Braekke (ed.), Impact of Acid Precip. on For. and Freshw. Ecosystems in Norway, SNSF-Project, Norway, IR 6/76, pp. 87-111.

16. Grahn, O. 1976. Proc. First Intl. Symp. Acid Precip. and the Forest Ecosys., pp. 519-530. USDA Forest Serv. Gen. Tech. Rep. NE-23.

17. Hendrey, G.R., K. Baalsrud, T.S. Traaen, M. Laake, and G. Raddum. 1976. Ambio 5:224-227.

18. Wile. Unpublished. Cited in Reference 2 of this paper, at 3-45.

19. Hendrey, G.R., and F.A. Vertucci. 1980. In Drablos and Tollan, op. cit., pp. 314-315.

20. Raddum, G.G. 1980. In Drablos and Tollan, op. cit., pp. 330-331.

21. Okland, K.A. 1980. SNSF-Project IR 52/80, 1432 Aas-NLH, Norway, 70 p.

22. Wiederholm, T., and L. Eriksson. 1977. Oikos 29:261-267.

23. Grahn, O., H. Hultberg, and L. Landner. 1974. Ambio 3:93-94.

24. Pough, F.H. 1976. Science 192:68-70.

25. Clark and Fisher (in prep.). Cited in Reference 2 of this paper, at 3-5-.

26. Beamish, R.J., and H.H. Harvey. 1972. J. Fish. Res. Board Can. 29:1131-1143.

27. Beamish, R.J. 1976. Water Air Soil Pollut. 6:501-514.

28. Schindler, D.W., R.H. Hesslein, R. Wagemann, and W.S. Broecker. 1980. Can. J. Fish. Aquat. Sci. 37:373-377.

29. Hikanson. Cited in Reference 2 of this paper, at 3-55.

30. Suns, K., C. Curry, and D. Russell. 1980. Environ. Can. Tech. Rep. LTS 80-1.

31. Jensen, K.W., and E. Snekvik. 1972. Ambio: 223-225.

32. Leivestad, H., and I.P. Muniz. 1976. Nature 359:391-392.

33. Harvey, H.H. 1979. Proc. Fifth Ann. Aquatic Toxicity Workshop, Hamilton, Ontario, Nov. 7-9, 1978. Fish. Mar. Serv. Tech. Rep. 862:115-128.

34. Pfeiffer, M., and P. Festa. 1980. NYSDEC Publication. FW-P168 (10/80), 58. p.

35. Schofield, C.L. 1976. Ambio 5(5-6):228-230.

36. Watt, W.D. 1980. Unpublished data from the Dept. Fish and Oceans, Halifax, N.S., Canada.

37. Nillsson, S.G., and I.N. Nillsson. 1978. Oikos 31:214-221.

38. McIntyre, J.W., and Manas. 1979. In S.A. Sutcliffe (ed.), The Common Loon, Proc. Second NA Conf. on Common Loon Res., Nat. Audubon Soc., N.Y.

39. Trivelpiece, S., A. Brown, R. Hicks, R. Fekete, and J.J. Volkman. 1979. Proc. N. Amer. Conf. on the Common Loon. pp. 45-55, Syracuse, N.Y. 162 p.

40. Glass, G.E., and O.L. Loucks (eds.). 1980. ERL-Duluth, EPA-600/3-80-044, May 1980. 187 p.

41. Herman, R., and J. Baron. 1980. In Drablos and Tollan, op. cit., pp. 218-219.

42. Baker, J.P., and C.L. Schofield. 1980. In Drablos and Tollan, op. cit., pp. 292-293.

NATIONAL ATMOSPHERIC DEPOSITION PROGRAM
A research program sponsored by the
Association of State Agricultural Experiment Stations
of the North Central Region • NC-141

October 12, 1981

Robert E. Yuhnke
Regional Counsel
Environmental Defense Fund
1657 Pennsylvania Street
Denver, CO 80203

Dear Mr. Yuhnke:

This is in response to your letter of October 8th in which you attached a summary report on acid rain research in the Intermountain West. I generally find the report well done and quite complete. I believe you have presented a reasonably balanced approach to the question of atmospheric deposition and its potential impact in Colorado and the mountain West. I will make several comments which amplify a couple of points and in several cases question somewhat the interpretation of data. I also enclose a recent set of comments that I made in a hearing held in Denver. I think for the most part these are in close agreement with most of your document.

COMMENTS

1. Page 2, paragraph 3 and pages 6 and 7.
   I do not wish to get involved in a debate with fellow researchers in this area but I have heard some discussion of the techniques used by Lewis and Grant to collect and analyze the samples which were used as a basis for the proposed upward trend in acidity from 1975 through 1978. These comments concerning their technique lead me to question the validity of the results. It is also very difficult from a theoretical point of view to understand how there could be such a large change in pH or acidity over a three year period. In addition, I think the point you make that the high nitrate levels are the result of an upslope phenomena is absolutely correct. The three NADP monitoring stations on the east slope, that is, Manitou, Rocky Mountain Park and Pawnee Grasslands all show nitrate levels which account for 45% of the acidity. The stations on the west slope show a contribution of 30-35% which is quite close to the national average. I think this is further verification along with the work of Huebert at Colorado College that automotive emissions and thus nitrates account for a larger proportion of the total acidity in eastern Colorado. I would also second your statement on page 7 about the use of older data on which to base trends. We are finding for example that some of the data we have collected

for our study in the Rocky Mountain Assessment Program from Yellowstone Park is difficult to analyze. Too little documentation exists and complete analyses are not available. Even the monitoring data of Junge for the 1955 period which has been widely quoted has serious problems in interpretation. This is extremely unfortunate since we have far too little data upon which to base historical trends.

2. You correctly point out the fact that in the lower elevations in the west relatively well buffered and alkaline soils exist which relates to two aspects of the problem. One is that these soils are immune to effects by acid precipitation and, in fact, the nitrate and sulfate inputs have been shown to act as fertilizers. Agricultural practices in these areas call for the use of acidifying fertilizers such as ammonium sulfate. Secondly, the alkaline soil is carried into the atmosphere and washed out with the rain which does reduce the acidity of the sample. Data also indicates this same phenomena is active in the higher elevations as well but due to reduced amounts of alkaline soil materials in the atmosphere, it is not as effective at reducing pH. One other factor that is important in modification of pH, particularly at the lower elevations, is ammonia. The amount of ammonia in the atmosphere has been somewhat of a surprise and it is the component primarily responsible for the difference in pH between Rocky Mountain National Park and Pawnee (see attached hearing comments).

3. I would suggest that if rainfall continues to increase in acidity, another problem at higher elevation could be the effect on forests. These are certainly more highly buffered than the headwater mountain lakes and streams but in some areas these forest systems may also be vulnerable.

4. You rightfully mentioned the question of comparison of data from various sampling networks and different sampling periods historically. We have made a major effort to provide for a reliable quality assurance program which is directed by the U.S. Geological Survey. I have recently reviewed some yearly average data from the entire network and calculated pH based on the total anion and cation concentrations. It is interesting that in most cases we can calculate the pH within 0.1 of a pH unit. The few sites where this was not possible have fairly alkaline pH's which require more sophisticated equilibria calculations to arrive at exact pH's. This is reassuring in that it indicates data of high quality.

5. On page 13, paragraph 1, you indicate the need for a greater degree of precipitation sampling by the Federal Land Management Agencies. I would point out two things; (1) these agencies are continuing to add deposition stations to the network and will in fact be the major contributor to deposition monitoring in western United States. It certainly is important that they be encouraged to continue this activity and that the funds be available in the future, (2) the data that we are now beginning to see from the network in the U.S.

indicates that it may not be necessary to have as many monitoring stations as we originally believed in order to provide adequate regional deposition patterns. We see a great deal of similarity between stations over a fairly large region. For example, the data for Ohio, West Virginia, Pennsylvania is reasonably consistent among all of the monitoring sites. In the western U.S. sites seem to divide into two major categories; (1) high elevation less affected by alkaline soil particulate matter and (2) low elevation with high pH's due to acid neutralization. It turns out that the nitrate and sulfate concentrations are not nearly so variable and if one calculates the *potential* pH based on sulfate and nitrate concentrations (sulfuric and nitric acid) before neutralization one would obtain reasonably comparable pH's over a very large area. I certainly believe we need more stations in some areas than we have today but we do not, for example, need the numbers that are in place in Colorado.

6. One point which you did not seem to touch upon is a question of deposition of particulates and aerosols. We do not know how to measure these deposition rates realistically, but from data in Canada and the eastern U.S. as well as Norway, one can infer that particulates and aerosol deposition is of equal, or maybe in some cases, greater importance. Also, there is the question of nitric acid vapor (subject of Huebert's research). I believe that it will be shown in the long run, at least in the eastern U.S., that particulates and aerosol deposition of acid sulfates are equivalent to those of wet deposition. I have not heard of anyone who is willing to make estimates for the western U.S., however on the average we may be looking at only half the total deposition when confining our calculations to wetfall.

7. Finally, I would like to comment on some recent testimony from EPA relating to the NO_x emissions. I briefly discussed this in the attached comments. It certainly is true that when nitrate is incorporated into biological systems (plant, microbial activity, etc.) that this is an effective neutralization step since protons are taken up and incorporated into the biological system. If nitric acids were completely consumed in this fashion in the soils for example, no net acidity would be experienced. However, we do not know that in all systems that this reaction is complete and that none of the acid nitrate is released either in the ground or surface waters. It is likely that it is essentially complete in many ecosystems. However, this does not in any way protect various materials such as marble, iron, etc., from damage nor, it is my guess, it does not protect headwater lakes and streams in areas like the Rocky Mountains. In these cases, much of the water enters directly from snowmelt and/or washes over rocks and unvegetated gravel. Thus, I do not believe these arguments that EPA is currently making justify lowering the NO_x emission standards for automobiles. It is certainly a question on which additional research is needed since there is some truth to the argument.

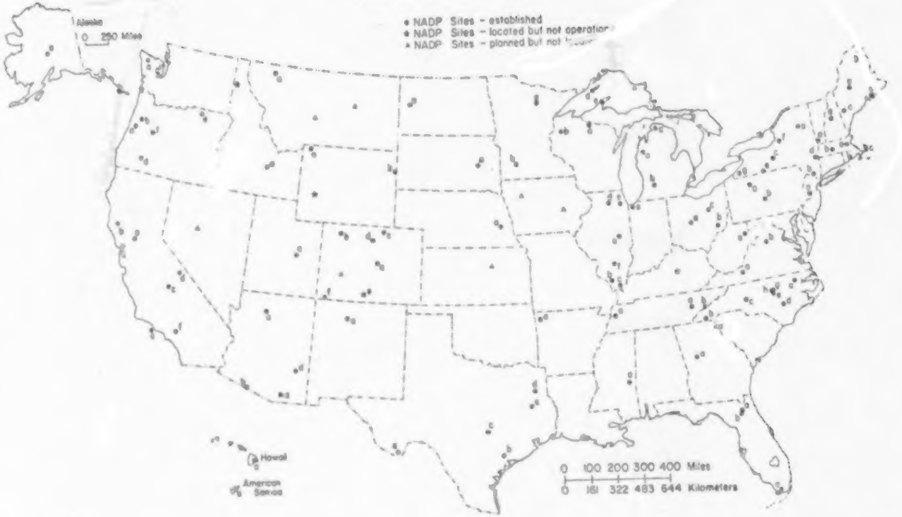
Again, I wish to state that I think you have prepared an excellent, well balanced report. I hope these comments and the attached statement are of help to you.

Sincerely,

James H. Gibson
Director,
Natural Resource Ecology
Laboratory and
Coordinator,
National Atmospheric Deposition
Project

Reference Address: Dr. Barry Huebert
Department of Chemistry
Colorado College
Colorado Springs, CO 80903

JHG/kam
Attachment



NADP MONITORING NETWORK

● NADP Sites – established
◆ NADP Sites – located but not operation
▲ NADP Sites – planned but not [illegible]
Alaska
0 250 Miles
Hawaii
American Samoa
0 100 200 300 400 Miles
0 161 322 483 644 Kilometers

9/15/81

NATIONAL ATMOSPHERIC DEPOSITION PROGRAM SITES (Continued)

State	Code #	Site Name	County	Agency	Individual	Latitude	Longitude
New Jersey (a)	312980	Washington Crossing	Mercer	EPA/NOAA/WMO	J. Miller	40°18'	74°51'
New Mexico (a)	320980	CUBA	Sandoval	USDI-BLM	C. Anderson	36°02'	106°58'
New York (c)	330860	Aurora Research Farm	Cayuga	SAES-Cornell University	W.W. Knapp	42°44'	76°39'
New York (g)	331000	Chautauqua	Chautauqua	Niagara Mohawk Power	R. M. Wood	42°17'	79°22'
New York (d)	331220	Knobit	Columbia	NY State Electric & Gas	D. Matias	42°07'	73°31'
New York (a)	332020	Huntington Wildlife	Essex	State U. of NY, Syracuse	D.J. Raynal	44°00'	74°13'
New York (b)	335140	Stilwell Lake-West Point	Orange	U. S. Military Acad.	Maj. J.K. Robertson	41°21'	74°02'
New York (f)	335240	Bennett Bridge	Oswego	Niagara Mohawk Power	R. M. Wood	43°30'	75°57'
New York (e)	336500	Jasper	Steuben	NY State Electric & Gas	D. Matias	42°07'	77°32'
No. Carolina (a)	340320	Lewiston	Bertie	SAES-N. Carolina St. & USGS	R.I. Bruck	36°08'	77°10'
No. Carolina (b)	341180	Research Triangle Institute	Durham	EPA	W. C. Eaton	35°54'	78°52'
No. Carolina (b)	342500	Coweeta	Macon	USDA-FS	J.E. Douglass	35°03'	83°27'
No. Carolina (y)	343310	Research Triangle Park	Durham	EPA/NOAA/WMO	J. Miller	35°52'	78°47'
No. Carolina (c)	343460	Piedmont Research Station	Rowan	SAES-N. Carolina St. & USGS	R. I. Bruck	35°40'	80°34'
No. Carolina (d)	343560	Clinton Crops Res. Stn.	Sampson	SAES-N. Carolina St. & USGS	R.I. Bruck	35°01'	78°17'
No. Carolina (e)	344160	Finley (Raleigh)	Wake	USDA-SEA & USGS	A. S. Heagle	35°44'	78°41'
No. Dakota (a)	350700	Theodore Roosevelt Nat'l Park	McKenzie	USDI-NPS	R. Powell	47°36'	103°15'
Ohio (a)	361760	Delaware	Delaware	USDA-FS	L.S. Dochinger	40°17'	83°04'
Ohio (b)	364900	Caldwell	Noble	SAES-OH Ag. Res. & Dev. Ctr.	T.C. Weidensaul	39°47'	81°31'
Ohio (c)	367160	Wooster	Wayne	SAES-OH Ag. Res. & Dev. Ctr.	T.C. Weidensaul	40°46'	81°56'
Oregon (a)	380200	Alsea Guard Ranger Station	Benton	EPA	C. F. Powers	44°22'	123°36'
Oregon (b)	380201	Schmidt Farm	Benton	EPA	C. F. Powers	44°38'	123°12'
Oregon (d)	380840	Lost Creek (Medford)	Jackson	USDI-BLM	G. Ferry	42°40'	122°[illegible]7'
Oregon (f)	381020	H. J. Andrews Exper. Forest	Lane	USDA-FS	A. McKee	44°15'	122° 0'
Oregon (c)	381120	Vines Hill (Vale)	Malheur	USDI-BLM	G. Ferry	43°54'	117°25'
Oregon (e)	381780	Pendleton	Umatilla	EPA/NOAA/WMO	J. Miller	45°41'	[illegible]
Pennsylvania (a)	392940	Kane Exp. For.	Elk	USDA-FS	D.A. Marquis	41°33'	[illegible]46'
Pennsylvania (b)	394200	Leading Ridge	Huntingdon	SAES-Penn. State Univ.	J.A. Lynch	40°39'	[illegible]7°56'
S. Carolina (a)	421880	Clemson	Pickens	SAES-Clemson University	U.S. Jones	34°40'	82°50'
S. Dakota (a)	430060	Huron	Beadle	EPA/NOAA/WMO	J. Miller	44°23'	[illegible]
Tennessee (a)	440040	Walker Branch Watershed	Anderson	Oak Ridge National Laboratory	S. E. Lindberg	35°58'	84°17'
Tennessee (b)	441190	Great Smoky Mtn. Nat. P.	Sevier	USDI-NPS	R. C. Mathews	35°43'	83°20'
Texas (a)	450425	Big Bend Nat. Park	Brewster	USDI-NPS	M. Warren	29°10'	103°12'
Texas (d)	452180	Longview	Gregg	Texas Air Control Board	S. Spaw	32°23'	94°43'
Texas (e)	453800	Forest Seed Center	Nacogdoches	Int. Paper Company	W. G. Mumford	31°33'	94°52'
Texas (c)	455210	McKinney Falls State Park	Travis	Texas Air Control Board	S. Spaw	30°12'	97°43'
Texas (b)	455350	Victoria	Victoria	EPA/NOAA/WMO	J. Miller	28°51'	96°55'
Utah (a)	460280	Cedar Mountain	Emery	USDI-BLM	W. W. Wagner	39°10'	110°37'
Vermont (a)	470100	Bennington	Bennington	Vt. Agency Environ. Conserv.	R. L. Poirot	42°52'	73°08'
Virginia (a)	481300	Horton's Station.	Giles	SAES-VPI & State Univ.	J. Skelly	37°11'	80°25'
Virginia (b)	482890	Shenandoah National Park		USDI-NPS	J. Skelly	38°31'	78°26'
Washington (a)	491410	Olympic Nat. Park (Hoh R.)	Jefferson	USDI-NPS	B. Moorhead	47°50'	123°55'
West Virginia (a)	501800	Parsons	Tucker	USDA-FS	S. H. Kunkle	39°06'	79°39'
Wisconsin (a)	513640	Trout Lake	Vilas	EPA	R. Becker	46°02'	89°38'
Wisconsin (b)	513700	Spooner	Washburn	EPA	R. Becker	45°50'	91°52'
Wyoming (b)	520820	Newcastle	Weston	USDI-BLM	T. K. Eskow	43°52'	104°11'
Wyoming (a)	520860	Yellowstone Nat. Park	Park	USDI-NPS	W. Hamilton	44°45'	110°35'
American Samoa (a)	530190	Samoa		EPA/NOAA/WMO	J. Miller	14°15'	170°34'

NATIONAL ATMOSPHERIC DEPOSITION PROGRAM SITES

State	Code #	Site Name	County	Agency	Individual	Latitude	Longitude
Alaska (a)	020390	Denali (McKinley) N'l. Pk		USDI-NPS	J. DalleMolle	63°48'	148°59'
Arizona (a)	030180	Tombstone	Cochise	SAES-Univ. of Arizona	R. Bohn	31°43'	110°41'
Arizona (d)	030360	Oliver Knoll	Graham	USDI-BLM	D. C. Herkhof	33°04'	109°52'
Arizona (c)	030370	Grand Canyon National Park		USDI-NPS	L. May	36°04'	112°10'
Arizona (b)	030620	Organ Pipe Cactus N.M.	Pima	USDI-NPS	W. F. Wallace	31°57'	112°47'
Arkansas (a)	042700	Fayetteville	Washington	SAES-Univ. of Arkansas	G. H. Wagner	36°05'	94°10'
California (d)	053460	Bishop	Inyo	EPA/NOAA/WMO	J. Miller	37°22'	118°22'
California (f)	054200	Tanbark Flat (San Dimas)	Los Angeles	USDA-FS	P. R. Miller	34°12'	117°46'
California (b)	054340	Hopland	Mendocino	USDI-BLM	N. Ritchey	39°00'	123°05'
California (c)	057530	Sequoia-King's Canyon N. P.	Tulare	USDI-NPS	L. Bancroft	36°35'	118°46'
California (e)	058500	Channel Islands Nat'l Park	Ventura	USDI-NPS	Nick Whelan	34°01'	119°22'
California (a)	058840	Davis Site	Yolo	SAES-Univ. of California	R.H. Burgy	38°32'	121°46'
Colorado (e)	060060	Alamosa	Alamosa	EPA/NOAA/WMO	J. Miller	37°27'	105°52'
Colorado (f)	061530	Mesa Verde National Park	Montezuma	USDI-NPS	J. E. Smith	37°11'	108°29'
Colorado (b)	061560	Sand Spring	Moffat	USDI-BLM	D. Bray	40°30'	107°42'
Colorado (d)	061910	Rocky Mountain National Park	Larimer	USDI-NPS	D. R. Stevens	40°21'	105°33'
Colorado (a)	062120	Manitou	Teller	USDA-FS	D.O. Fox	39°06'	105°05'
Colorado (c)	062220	Pawnee	Weld	SAES-Colorado State Univ.	J.H. Gibson	40°47'	104°45'
Florida (b)	100020	Austin-Cary Forest	Alachua	SAES-Univ. of Florida	H. Riekerk	29°45'	82°15'
Florida (a)	100360	Bradford Forest	Bradford	SAES-Univ. of Florida	H. Riekerk	29°58'	82°12'
Florida (c)	101190	Everglades National Park	Dade	USDI-NPS	P. Rosendahl	25°20'	80°40'
Georgia (a)	114140	Georgia Station	Pike	SAES-Univ. of Georgia	J.T. Walker	33°11'	84°24'
Hawaii (a)	120080	Mauna Loa	Hawaii	EPA/NOAA/WMO	J. Miller	19°32'	155°12'
Idaho (a)	130340	Craters of the Moon	Butte	USDI-BLM	K. Gebhardt	43°28'	113°34'
Illinois (a)	141160	Bondville	Champaign	SAES-Univ. of Illinois	G.J. Stensland	40°03'	88°22'
Illinois (d)	141800	NIARC	Dekalb	SAES-Univ. of Illinois	R. Bell	41°50'	88°51'
Illinois (e)	141980	Argonne	DuPage	Argonne National Laboratory	M. L. Wesley	41°42'	87°59'
Illinois (b)	143580	SIU	Jackson	SAES-Southern Ill. Univ.	G.M. Aubertin	37°42'	89°16'
Illinois (f)	144740	Salem	Marion	EPA/NOAA/WMO	J. Miller	38°39'	88°58'
Illinois (c)	146340	Dixon Springs Ag. Ctr.	Pope	SAES-Univ. of Illinois	C.J. Kaiser	37°26'	88°40'
Indiana (a)	153420	Indiana Dunes Nat. Lakeshore	Porter	USDI-NPS	J. R. Whitehouse	41°38'	87°05'
Maine (d)	200010	Acadia National Park	Hancock	Maine Dep. Environ. Protection	L. Carver	44°23'	68°14'
Maine (b)	200045	Caribou	Aroostook	EPA/NOAA/WMO	J. Miller	46°52'	68°01'
Maine (c)	200277	Bridgton	Cumberland	Maine Dep. Environ. Protection	L. Carver	44°06'	70°43'
Maine (a)	200935	Greenville Station	Piscataquis	SAES-Univ. of Maine	S. A. Norton	45°25'	69°40'
Massachusetts (c)	220155	NACL	Barnstable	USDI-NPS	M. K. Foley	41°53'	70°01'
Massachusetts (b)	220815	Caldwell Creek	Hampshire	SAES-Univ. of Mass.	D. L. Mader	42°19'	72°23'
Massachusetts (a)	221325	East	Middlesex	SAES-Univ. of Mass.	W. A. Feder	42°22'	71°14'
Michigan (c)	230920	U of M Biological Station	Cheboygan	SAES-Michigan State Univ.	J. Boyle	45°34'	84°41'
Michigan (e)	232240	Houghton	Houghton	USDI-NPS & EPA	Robert Stottlemyer	47°14'	88°32'
Michigan (d)	232570	Isle Royale National Park	Keweenaw	USDI-NPS	Robert Stottlemyer	47°54'	89°09'
Michigan (b)	232660	Kellogg Biological Station	Kalamazoo	SAES-Michigan State Univ.	J. B. Hart, Jr.	42°25'	85°23'
Michigan (a)	235340	Wellston	Wexford	USDA-FS	D.H. Urie	44°13'	85°51'
Minnesota (a)	241660	Marcell Exp. Forest	Itasca	USDA-FS	E.S. Verry	47°30'	93°28'
Minnesota (c)	241840	Fernberg	Lake	EPA, ERL, & Forest Service	G. Glass	47°58'	91°29'
Minnesota (b)	242720	Lamberton	Redwood	SAES-Univ. of Minnesota	W. W. Nelson	44°15'	95°19'
Mississippi (a)	251460	Meridian	Lauderdale	EPA/NOAA/WMO	J. Miller	32°20'	88°45'
Montana (a)	270570	Glacier National Park	Flathead	USDI-NPS	D. Lang	48°30'	113°59'
Nebraska (a)	281520	Mead	Saunders	SAES-Univ. of Nebraska	S.B. Verma	41°09'	96°30'
New Hampshire (a)	300240	Hubbard Brook	Grafton	USDA-FS	J. Hornbeck	43°57'	71°42'

NATIONAL ATMOSPHERIC DEPOSITION PROGRAM
A research program sponsored by the
Association of State Agricultural Experiment Stations
of the North Central Region • NC-141

COMMENTS

CLEAN AIR ACT HEARING - DENVER, OCTOBER 8, 1981

James H. Gibson, Director
Natural Resource Ecology Laboratory
Colorado State University
Fort Collins, Colorado
(303) 491-5571

I am also national program coordinator for the National Atmospheric Deposition Program (NADP) which is supported by the State Agricultural Experiment Stations, USDA, Department of Interior (BLM, NPS, USGS), Department of Commerce (NOAA), EPA and other federal and state agencies and private corporations. The NADP objectives include development and operation of a long-term nationally distributed atmospheric deposition monitoring network, as well as research programs related to acid rain effects on agriculture, forests, freshwater lakes and streams and materials.

I. Nature and characteristics of data base upon which these comments are based.

- A. The data have been generated from a national monitoring network initiated in 1978 with 18 stations - now over 90 stations covering the continental U.S., Alaska, Hawaii, American Samoa.
- B. Weekly, wet only, precipitation samples are collected and analyzed. Dry deposition is collected 6 times yearly.
- C. A total chemical analysis is made of the major chemical components of the sample which is carried out by a single analytical laboratory for the entire network. Complete chemical analysis is required since the pH determination alone is not sufficient information upon which to base conclusions concerning the nature of acidity, its origin, its effects and the effectiveness of air quality regulations in determining future acidity trends.
- D. Monitoring stations are located in areas removed from local sources such as urban areas, power plants, etc. so as to generate regional patterns of chemical deposition information.

E. The monitoring program is designed to support the determination of current and future effects of deposition on agriculture, forestry, freshwater lakes and streams, as well as materials damage.

F. The network is designed for long-term monitoring (in excess of 10 years) since short-term monitoring does not provide information on average deposition which is important to evaluating effects. It is also not possible to discern long-term trends with less than 5 years data.

II. Evaluation of data - status of Colorado - data reviewed are 12-month averages, October, 1979 to September, 1980 - normal rainfall is assumed to have a pH of 5.6.

A. Yearly average pH - Colorado network sites.

1. 5.6 - Pawnee Grasslands, northeast of Fort Collins.
2. 4.9 - Manitou Experimental Forest, west of Colorado Springs.
3. 4.9 - Craig
4. 5.7 - Alamosa
5. 5.0 - Rocky Mountain National Park

B. During this period there were no weekly samples with pH values measured below 4.0. Lowest in State - Craig - 4.2.

C. If good chemical analyses are obtained of the major chemical components (NO_3, SO_4, Cl, Na, K, Ca, Mg, NH_4) then the pH can be calculated. The pH for the entire monitoring network can generally be calculated within 0.1 pH units of the measured value.

D. The agreement between the measured and the calculated pH values allows us to come to the following conclusions:

1. The data base is of high quality
2. Sulfate and nitrate (sulfuric and nitric acids) are the only constituents contributing significantly to rainfall acidity. (Precursors for these acids are SO_4 and NO_x which are converted in the atmosphere to sulfuric and nitric acids.)
3. The wide variation of pH in Colorado is due to acid neutralization primarily by alkaline dust (Ca and Mg) and ammonia rather than variations in sulfate and nitrate levels. If not for neutralization of these acids by dust and ammonia, pH in Colorado would range from 4.2 to 4.4, a variation of only 0.2 pH units.

4. At Colorado sites, 80 to 120% of acidity is neutralized depending upon the site location. Low elevation arid areas with alkaline soils demonstrate highest neutralization.
5. On the west slope, 35% of the total acidity is contributed by nitrate. On the east slope, including Rocky Mountain National Park, 44% is contributed by nitrate. This suggests automotive emissions are a large factor on the east slope.
6. Data demonstrates that the sulfate and nitrate levels are anthropogenic or man-caused. Compared to remote sites such as Alaska and Olympic National Park, the Colorado levels of sulfate are 3 to 4 times those in these remote areas while nitrate is 9 to 10 times higher. This compares with v[illegible]s of sulfate in the eastern U.S. which are 10 times the remote [illegible] with nitrates 20 times higher. Since there are no significant natural sources in the continental U.S. and Canada, these increases can only be explained by man-caused emissions of SO_2 and NO_x.

III. Present and future significance of acid rain to Colorado.
   A. Colorado is currently experiencing acid rain in some areas, primarily high elevations.
   B. Average values of pH are not as low as some data which have been reported for the State.
   C. Lowest pH values are in the mountains where sensitive ecosystems exist.
   D. Sensitive areas in the mountains are related to insoluble geologic materials with little or no capacity to neutralize (buffer) deposited acids.
   E. The greatest threat of acidification is to lakes and streams near headwaters. This is related to higher acidities of rainfall (low pH) and higher rainfall amounts.
   F. Acidification of lakes and streams (below pH 5.5-6.0) will threaten fish populations.
   G. Forested areas of the mountains would be the next potentially threatened areas.

H. Low elevation areas have alkaline (well-buffered) soils and are not threatened. Sulfate and nitrate are fertilizers and may be beneficial. Also, these areas receive low rainfall and thus, have low deposition rates.

I. Nitrate is a relatively large contributor to acidity in Colorado, especially on the east slope and is likely associated with automotive emissions.

J. The data indicates we have consumed approximately 100% or more of the neutralizing capacity of atmospheric dust and ammonia and thus future increases in nitrate and sulfate (nitric and sulfuric acids) will have a relatively larger impact. For example, if the sulfate concentrations were doubled, the pH of the sites previously listed would range from 4.3 to 4.6, rather than 4.9 to 5.7. In the Eastern U.S. only 30 to 40% of the acids are now neutralized.

IV. Opinion.

Colorado has not yet suffered significant damage but with the average pH values dropping below 5 and with exhaustion of the atmospheric neutralization capacity, I believe high lakes and streams could be threatened in the future, especially if there is any significant increase in sulfate and nitrate (SO_2 and NO_x) emission levels. Nitrate is a significant factor with estimated 40 to 50% contribution to acidity on the east slope. This is most likely related to automotive sources, and thus I see no justification for lowering the standards on automotive emissions (mobile sources are estimated to contribute 45% of NO_x). It has been argued that nitric acid is not a significant factor in acidification since, when it is taken up by biological processes (plant, microbial, etc.), the acid is effectively neutralized. While this is true and may be important for areas such as forests, this does not protect materials from corrosion and damage nor will it likely protect high mountain lakes and streams where runoff is over rocky, non-vegetated areas or is introduced into the lakes and streams directly from snowmelt. The full answer to this question will require additional research.

Looking at the larger picture, while the significance of acid rain to Colorado may be debatable at this time, such is not the case in the eastern part of the United States and Canada where acidities run 10 times as great as

Colorado (pH's of 4 to 4.1) and rainfall is 3 to 4 times as large, further contributing to total acid deposition. There it has been demonstrated that there has been a loss of fish populations in such areas as the Adirondack Mountains of New York State and the lake district of eastern Canada. In addition, there appears to be growing evidence of the demonstrable loss of forest productivity in the Eastern U.S. and Canada. Since nitric acid and sulfuric acid are proven to be the basis of acidity, we should be looking to lowering emissions of NO_x and SO_2, not relaxing standards. It is important to realize that many of the effects we are seeing, or suspect, are likely not reversible, and therefore, it is critical that action is taken before such effects are wide spread.

THE ROCKY MOUNTAIN BIOLOGICAL LABORATORY
CHARTERED [illegible] JOHN C. JOHNSON FOUNDER
A HIGH ALTITUDE FIELD STATION WELCOMING BIOLOGISTS OF ALL DISCIPLINES
CRESTED BUTTE, COLORADO 81224

October 2, 1981

Reply to: 127 Langmuir Lab.
Cornell University
Ithaca, NY 14850

Mr. Robert B. Lewis
Environmental Research Group
P.O. Box 2190
Aspen, Colorado 81612

Dear Bob:

I'm sending you this letter so you can read it at the Federal Clean Air Act hearings in Denver next week. I hope you'll have an opportunity to do so.

As you know, RMBL scientist John Harte and his team have been measuring the acidity of the precipitation in the Gothic, Colorado, area for the past two years. He has recorded pH values as low as 3.6; last summer's average was about 4.5, slightly less acid than tomato juice. These measurements, the first reported for the Western Slope, are consistently lower than those published for Como Creek on the Eastern Slope by Drs. Bill Lewis and Mike Grant from the University of Colorado. (Lewis, W.M. Jr. and M.C. Grant, Science 207: 176-177, 1980). Since all three of these men are careful scientists whose measurements are made with only the highest standards of accuracy, one can only conclude that Colorado is receiving substantial doses of acid precipitation and that the western slope is being hit hardest.

The effect of acid precipitation on aquatic ecosystems is well documented. Thousands of lakes in Scandanavia, the Adirondack Mountains of New York, Eastern Canada, and several other places are essentially biologically dead except for a few acid-tolerant species of algae and bacteria. The fish are gone, and much of the plankton and aquatic insects that support their food chains are gone with them. For most of these lakes, even if the acid input stops, there will be little, if any, recovery within our lifetime.

The effect of acid precipitation on an aquatic ecosystem is directly related to that system's buffering capacity. High carbonate lakes, for example, can absorb considerable acid input before major changes in pH occur. However, Dr. Harte's measurements in the Galena Lake-Mexican Cut area of the Elk Mountains clearly show that this watershed has very limited buffering capacity, and hence is a likely candidate to follow the pattern documented in the Adirondacks very soon. One need only glance at a geological map of Colorado to see that limited buffering capacities are probably typical, rather than exceptional, in most of montane Colorado.

In addition to the direct biological effects of decreasing pH, acidification of a water body releases many toxic metals, previously sequestered in bottom sediments, into the water column. These metals are not only poisonous to aquatic life, they are poisonous as well to other wildlife and humans who happen to drink the water. Because of the highly mineralized nature of the Colorado mountains, it appears that this phenomenon will be very serious. Furthermore, only a tiny percentage of Colorado's land area (about 2% - the subalpine and alpine meadows, many of which are in the "mineral belt"), furnishes over 25% of its runoff. It is painfully clear that acidification of these areas will have disastrous effects on downstream fish and wildlife populations, and on irrigation water and domestic water supplies derived from surface runoff. The last is especially serious, since there is increasing evidence that some metals, probably released by acid runoff, are responsible for certain kinds of birth defects.

Aside from its effects on aquatic ecosystems, there is increasing evidence that acid precipitation can adversely affect the productivity of forest and agricultural ecosystems as well as cause significant and deleterious changes in soils. For all these reasons I have previously stated publicly - and will state again - that acid precipitation is the most insidious threat facing the ecological integrity of our region.

Although the acid precipitation phenomenon may occasionally result in localized areas from "natural" occurrences, there is overwhelming evidence (contrary to assertions of the utility industry) that the vast majority of it is human-caused, specifically from the burning of fossil fuels. If there is any chance that the current trends toward the acidification of alpine and subalpine ecosystems are going to be reversed, it will come from strengthening, not gutting, the Clean Air Act. Emission standards for oxides of sulfur and nitrogen must be made more stringent, and these standards must be enforced.

If this is not done, we will be able to witness the biological death of our high mountain ecosystems, and see increasing amounts of toxic metals appear downstream, to be deposited in agricultural ecosystems (where they will directly enter the human food chain), and domestic water supplies. This would be a shameful legacy to leave our children.

Sincerely yours,

Pete

Peter F. Brussard
Director

PFB:esc

97TH CONGRESS
1ST SESSION

S. 1706

To amend the Clean Air Act to better protect against interstate transport of pollutants, to control existing and new sources of acid deposition, and for other purposes.

IN THE SENATE OF THE UNITED STATES

OCTOBER 6 (legislative day, SEPTEMBER 9), 1981

Mr. MITCHELL (for himself, Mr. STAFFORD, Mr. CHAFEE, Mr. COHEN, Mr. DURENBERGER, Mr. HART, Mr. DODD, Mr. TSONGAS, Mr. RUDMAN, Mr. LEAHY, Mr. MOYNIHAN, and Mr. DANFORTH) introduced the following bill; which was read twice and referred to the Committee on Environment and Public Works

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A BILL

To amend the Clean Air Act to better protect against interstate transport of pollutants, to control existing and new sources of acid deposition, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That this Act may be cited as the "Acid Deposition Control Act".

SEC. 2. Title I of the Clean Air Act is amended by adding the following new part:

"PART E—INTERSTATE TRANSPORT AND ACID PRECURSOR REDUCTION

"FINDINGS AND PURPOSES

"SEC. 180. (a) The Congress finds that:

"(1) the long-range transport of pollutants and their transformation products is an interstate and international problem;

"(2) current levels of emissions of air pollutants from existing sources as well as increased emissions from new existing sources threaten public health and welfare and the environment in States and countries other then those in which emitted;

"(3) reduction of total regional atmospheric loading of pollutants such as sulfur oxides and nitrogen oxides will enhance protection of public health and welfare and the environment;

"(4) more effective regulation of the interstate transport of air pollutants is needed in order to protect the health and welfare of the citizens of downwind States and the economic growth opportunities of downwind States; and

"(5) in particular,

"(A) the deposition of acid compounds from the atmosphere is causing and contributing to widespread long-term ecosystem degradation;

"(B) the principal source of the acid compounds in the atmosphere, and their precursors, is the combustion of fossil fuels;

"(C) the problem of acid deposition is of national and international significance and cannot be addressed adequately without Federal intervention;

"(D) control strategies and technology for precursors to acid deposition exist now that are economically feasible; and

"(E) current and future generations of Americans will be more adversely affected by delayed action, so that efforts to remedy the problem should commence now.

"(b) The purposes of this part are to:

"(1) protect public health and welfare and the environment from any actual or potential adverse effect caused by ambient concentrations or deposition of air pollutants, including the products of atmospheric transformation of pollutants; and

"(2) preserve the rights and responsibilities of States to protect the public health and welfare and the environment of their citizens from air pollution originating in other States.

"ESTABLISHMENT OF REGION

"SEC. 181. (a) There is hereby established a long-range transport corridor, hereafter referred to as the "acid deposition impact region," consisting of the States of Alabama, Arkansas, Connecticut, Delaware, Florida, Georgia, Illinois, Indiana, Iowa, Kentucky, Louisiana, Maine, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, New Hamphire, New Jersey, New York, North Carolina, Ohio, Pennsylvania, Rhode Island, South Carolina, Tennessee, Vermont, Virginia, West Virginia, Wisconsin, and the District of Columbia.

"(b) The Administrator shall conduct a study of air pollution problems associated with long-range transport of pollutants in the portions of the continental United States not included in (a) of this section. Not later than two years after the enactment of this section, the Administrator shall report to the Congress the results of such study.

"ACID PRECURSOR CONTROLS

"SEC. 182. (a) Emissions of sulfur dioxide and of oxides of nitrogen from stationary sources in the acid deposition impact region established under section 181(a) of this Act shall not be allowed to increase over the total actual emissions of each pollutant in such region as of January 1, 1981. No major stationary source in such region shall significantly increase its emissions of sulfur dioxide or of oxides of nitrogen, unless there has been identified for such source in accordance with section 185 of this Act a net reduction in emissions of such pollution at one or more points in such region in excess of the proposed increase in emissions, and not otherwise required by a State implementation plan under section 110 of this Act or under section 183 or 184 of this Act.

"(b) There shall be achieved a reduction in annual emissions of sulfur dioxide in the acid deposition impact region established under section 181(a) of this Act of 10,000,000 tons from the total actual annual level of such emissions between January 1, 1980, and December 31, 1980. Such reduction shall be achieved pursuant to a phased reduction and completed no later than ten years after the enactment of this part.

"STATE SULFUR DIOXIDE REDUCTION REQUIREMENTS

"SEC. 183. (a)(1) Each State shall be required to achieve within its borders a reduction in annual sulfur dioxide emissions equal to that fraction of 10,000,000 tons which is the ratio of all the actual utility emissions in such State in excess of 1.2 pounds of sulfur per million British thermal units to the total in all States in the region of all the actual utility emissions in excess of 1.2 pounds of sulfur per million British thermal units.

"(2) The Governors of any two or more States within the region may by agreement reallot among agreeing States the reductions required under (a)(1) provided that the total reductions equal the total required under (a)(1).

"(b)(1) Not later than two years after the enactment of this part, each State shall adopt enforcement measures to achieve the reduction in sulfur dioxide emissions required by subsection (a) of this section, including emission limitations and schedules for compliance for sources within such State and other means of emission reduction in accordance with section 185 of this Act. The Governor of such State shall submit such measures to the Administrator for review in accordance with paragraph (2) of this subsection, and to the Governors of all other States in the acid deposition impact region for comment.

"(2) The Administrator shall approve within four months such measures submitted under paragraph (1) of this subsection if, taking into consideration the comments of Governors of other States in such region, the Administrator finds that such measures (A) contain enforceable requirements for continuous emission reduction, (B) contain requirements for monitoring by the source and enforcement agencies to assure that the emission limitations are being met, and (C) are adequate to achieve the required reduction in sulfur dioxide emissions for such State within the time specified in section 182(b) of this Act.

"(3) Each emission limitation, schedule for compliance or other measure adopted and approved under this subsection shall be deemed a requirement of the State implementation plan approved or promulgated for such State under section 110 of this Act.

"MAJOR STATIONARY SOURCE SULFUR DIOXIDE REDUCTION REQUIREMENTS

"SEC. 184. In any State in the acid deposition impact region established by section 181(a) of the Act which has not in accordance with section 183(b)(1) of this Act adopted measures to achieve the reduction required by section 183(a) of this Act within two years after enactment, or which has not had such measures approved by the Administrator under section 183(b)(2) of this Act within two years and four months after enactment of this Act, the owner or operator of each fossil-fuel-burning electric generating facility which is a major stationary source which is not subject to section 111(a) shall comply with an emission limitation or limitations for all such facilities owned or operated by the same entity equivalent to an average among such facilities of 1.2 pounds of sulfur per million British thermal units on a thirty-day average. The owner or operator of each such facility shall submit to the Administrator a plan and schedule of compliance for achieving such emission limitation or equivalent emission reduction in accordance with section 185 of this Act, not later than three years after the enactment of this part. The Administrator shall approve such plan and schedule for compliance if it (A) contains enforceable requirements for continuous emission reduction, (B) contains requirements for monitoring by the source and enforcement agencies to assure that the emission limitations are being met, and (C) will achieve the emission reduction required by this section at the earliest practicable date, but no later than ten years after the enactment of this part. Failure of such owner or operator to submit such approvable plan and schedule within three years after enactment of this part, failure to comply with the plan and schedule of compliance, and failure to achieve the emission reduction required by this section at the earliest practicable date, but no later than ten years after enactment of this Act, shall be violations of emission limitations for the purposes of sections 113, 120, and 304 of this Act.

"ENFORCEABLE EMISSION REDUCTION PROGRAMS

"SEC. 185. (a) For the purposes of maintaining the limitation on emissions required by section 182(a) of this Act or attaining emission reductions required by section 182(b), 183, or 184 of this Act, the following methods or programs for net emission reduction may be used by a State or the owner or operator of a source, if emission limitations under such methods or programs are enforceable by the Federal Government, States other than those in which the emissions occur, and citizens under section 304 of this Act:

"(1) least emissions dispatch to meet electric generating demand at existing generating capacity;

"(2) retirement of major stationary sources at an earlier date than provided in schedules on file with the Federal Energy Regulatory Commission, the Internal Revenue Service, or State utility regulatory agencies;

"(3) investments in energy conservation where reductions in emissions can be identified with such investments;

"(4) trading of emission reduction requirements and actual reductions on a State or regional basis, for which States and the Administrator are authorized to establish emission reduction banks or brokerage institutions to facilitate such trading; and

"(5) precombustion cleaning of fuels.

"(b) A State or the owner or operator of a source required to achieve emission reductions under section 182, 183, or 184 of this Act may substitute reduction in emissions of oxides of nitrogen for required reductions in emissions of sulfur dioxide, at a rate of two units by weight of oxides of nitrogen for each unit of sulfur dioxide.".

SEC. 3. Section 110(1)(2)(E) of the Clean Air Act is amended by inserting after "visibility," the following: "or

(III) contribute to atmospheric loadings of pollutants or their transformation products which may reasonably be anticipated to cause or contribute to an adverse effect on public health or welfare or the environment in any other State or foreign country.".

97TH CONGRESS
1ST SESSION

S. 1709

To amend the Clean Air Act to provide for a program to control acid precipitation.

IN THE SENATE OF THE UNITED STATES

OCTOBER 6 (legislative day, SEPTEMBER 9), 1981

Mr. MOYNIHAN introduced the following bill; which was read twice and referred to the Committee on Environment and Public Works

---

A BILL

To amend the Clean Air Act to provide for a program to control acid precipitation.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That this Act may be cited as the "Acid Precipitation Control Act of 1981".

STATEMENT OF FINDINGS

SEC. 2. The Congress finds that—

(1) manmade sulfur dioxide and nitrogen oxide emissions are known to be precursors of acid precipitation;

(2) sulfur dioxide and nitrogen oxide emissions are being transported through the atmosphere and deposited in both dry and wet forms in areas far from the original source of the emissions;

(3) current provisions of the Clean Air Act are not adequate to address the problem of acid precipitation and

(4) acid precipitation—

(A) is responsible for the elimination of aquatic life in hundreds of lakes in the United States and thousands of lakes in Canada;

(B) contributes to the increasing levels of heavy metal concentration in public reservoirs and water distribution systems that often exceed recommended standards for human health;

(C) is known to cause the corrosion of metals and erosion of buildings and statues made of calcareous rock resulting in substantial economic losses;

(D) can cause a retardation of a wide variety of forest growth;

(E) can cause adverse changes in the growth and development of crops;

(F) is likely to accelerate the processes of plant nutrient leaching from soil; and

(G) is an interstate and international problem.

IMPLEMENTATION PLANS

SEC. 3. Section 110(a)(2)(J) of the Clean Air Act is amended by inserting before the semicolon at the end thereof the following: ", and part E of this title (relating to acid precipitation control)".

ACID PRECIPITATION CONTROL PROGRAM

SEC. 4. Title I of the Clean Air Act is amended by adding at the end thereof the following new part:

"PART E—ACID PRECIPITATION CONTROL

"PURPOSES

"SEC. 181. The purposes of this part are—

"(1) to control acid precipitation by significantly reducing the precursor emissions of sulfur dioxide and nitrogen oxide from manmade sources;

"(2) to mitigate or prevent adverse ecological impacts and economic losses resulting from acid precipitation; and

"(3) to reduce the transport of air pollutants across international boundaries.

"DEFINITIONS

"SEC. 182. For the purposes of this part—

"(1) the term 'acid precipitation mitigation region' means the region consisting of the States of Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Ohio, Indiana, Illinois, Michigan, Wisconsin, Minnesota, Iowa, Missouri, Delaware, Maryland, the District of Columbia, Virginia, West Virginia, North Carolina, South Carolina, Georgia, Florida, Kentucky, Tennessee, Alabama, Mississippi, Arkansas, and Louisiana;

"(2) the term 'major stationary source' has the same meaning as defined in section 302(j);

"(3) the term 'major emitting powerplant' means a fossil-fuel-fired electric powerplant which—

"(A) had total 1980 annual sulfur dioxide emissions exceeding fifty thousand tons; and

"(B) had a 1980 annual sulfur dioxide emissions rate that exceeded three pounds;

"(4) the term 'sulfur dioxide emissions rate' means the number of pounds of sulfur dioxide emitted per million British thermal units of energy output; and

"(5) the term 'statewide utility sulfur dioxide emissions rate' means the number of pounds of sulfur dioxide emitted from all utility owned fossil-fuel-fired electric powerplants having a generating capacity greater than one megawatt within a State per million

British thermal units of energy output from all such powerplants.

"EMISSIONS REDUCTION REQUIREMENTS

"SEC. 183. (a)(1) Except as otherwise provided in paragraph (2), each State in the acid precipitation mitigation region shall be required to reduce, prior to December 31, 1991, sulfur dioxide emissions from all major stationary sources, as determined for the base year under subsection (b), by an amount equal to 85 per centum of the actual 1980 sulfur dioxide emissions from all major emitting powerplants within such States, but disregarding any emissions from a separate generating unit or units of such powerplants that are subject to the provisions of section 111 of this Act.

"(2) The amount of the reduction in sulfur dioxide emissions required under this subsection for any State shall not exceed—

"(A) in the case of any State having a 1980 annual statewide utility sulfur dioxide emissions rate equal to or less than two pounds, an amount equal to 50 per centum of the base year sulfur dioxide emissions (as determined under subsection (b)) from all fossil-fuel-fired electric powerplants having a generating capacity greater than one megawatt in such State; or

"(B) in the case of any State having a 1980 annual statewide utility sulfur dioxide emissions rate of more than two pounds, an amount equal to 75 per centum of the base year sulfur dioxide emissions (as determined under subsection (b)) from all fossil-fuel-fired electric powerplants having a generating capacity greater than one megawatt in such State.

"(b) For purposes of subsection (a), the base year emissions for major stationary sources and the base year emissions for any powerplant or group of powerplants shall be equal to the total actual annual amount of sulfur dioxide emissions in 1980 from any such major stationary source, from any such powerplant, or from any separate generating unit of such a stationary source or powerplant, which was in operation at any time during the calendar year 1980, but disregarding any such emissions which were in excess of the allowable emissions under the provisions of section 110(a)(2)(B) or section 111 of this Act.

"(c) The Administrator shall, within sixty days after the date of the enactment of this part, identify each major emitting powerplant within the acid precipitation mitigation region, using the best available data and methodology to determine the total actual 1980 sulfur dioxide emissions and the actual 1980 sulfur dioxide emissions rate for each major emitting powerplant.

"(d) The Administrator shall, within ninety days after the date of the enactment of this part, establish a sulfur dioxide emissions reduction requirement pursuant to subsection (a) for each State in the acid precipitation mitigation region, and shall, within one hundred and twenty days after the date of the enactment of this part, notify each State in such region of its sulfur dioxide emissions reduction requirement.

"PLAN REQUIREMENTS

"SEC. 184. (a) Each applicable State implementation plan shall, within one year after the date of the enactment of this part, be amended so as to contain emissions limitations, schedules, and timetables for compliance with such limitations, or such other enforceable measures as may be necessary for meeting the sulfur dioxide emissions reduction requirement specified under section 183 by December 31, 1991. Such other measures may include, but are not limited to, the trading of emissions offsets within the acid precipitation mitigation region, early retirement of sources, and energy conservation.

"(b) In meeting its total sulfur dioxide emissions reduction requirement, a State may substitute a reduction in nitrogen oxide emissions for a reduction in sulfur dioxide emissions, in a ratio of two parts nitrogen oxide to one part sulfur dioxide.

"(c)(1) In meeting its emissions reduction requirement by December 31, 1991, no State shall be allowed to include any reduction in emissions from any major stationary source, or separate generating unit thereof, which was in operation before December 31, 1980, to the extent that such reduction represents compliance with Federal emission standards other than those imposed under this part.

"(2) In meeting such requirement by December 31, 1991, a State may include any reduction in emissions from a major stationary source, or separate generating unit thereof, which was not in operation before December 31, 1980, to the extent that such reduction is greater than the reduction required under Federal emission standards other than standards imposed under this part.

"AUTHORITY OF THE ADMINISTRATOR

"SEC. 185. (a)(1) The Administrator shall, within ninety days after submission of all plan amendments pursuant to section 184, review each applicable State implementation plan and make a finding as to whether the plan amendments will insure that a State's sulfur dioxide emissions reduction requirement will be met by December 31, 1991. The Administrator shall approve any such plan amendments or parts thereof which he determines will insure that such emission reduction requirement will be met by December 31, 1991.

"(2) If the Administrator finds, pursuant to paragraph (1), that a State's plan amendments or parts thereof submitted pursuant to section 184 will not insure that such State's sulfur dioxide emissions reduction requirement will be met by December 31, 1991, the Administrator shall promptly, but in no event later than six months after making such a finding, prepare and publish revisions to such State's implementation plan setting forth emission limitations, schedules, and timetables for compliance with such limitations, or other such measures (as described in section 184(a)) as may be necessary to insure that such State's sulfur dioxide emissions reduction requirement will be met by December 31, 1991.

"(b)(1) The Administrator shall periodically, but not less often than every three years after approval of an amendment to a State implementation plan under subsection (a), review each such plan and make a finding as to whether such plan continues to insure that such emissions reduction requirement will be met by December 31, 1991.

"(2) If the Administrator finds, pursuant to paragraph (1), that a State implementation plan no longer insures that such emissions reduction requirement will be met by December 31, 1991, the Administrator shall take actions to insure compliance in the same manner as provided in [illegible] (a)(2).

"(c) If, at any time, the Administrator determines that a State is not carrying out its State implementation plan in a manner which insures that such emissions reduction requirement will be met by December 31, 1991, the Administrator shall, in addition to any other penalties or enforcement proceedings authorized under this Act, apply such additional sanctions or limitations on emissions with respect to any major emitting powerplant in such State as the Administrator determines to be necessary to insure that such requirement will be met by December 31, 1991.".

97TH CONGRESS
1ST SESSION

S. 1718

To amend the Clean Air Act with respect to interstate pollution abatement.

IN THE SENATE OF THE UNITED STATES

OCTOBER 7, 1981

Mr. DODD (for himself and Mr. DURENBERGER) introduced the following bill; which was read twice and referred to the Committee on Environment and Public Works

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A BILL

To amend the Clean Air Act with respect to interstate pollution abatement.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That (a) section 110(a)(2)(E) of the Clean Air Act is amended to read as follows:

"(E) it contains adequate provisions (i) prohibiting a source or sources within the State from emitting any air pollutant in amounts which will (I) interfere with the attainment or maintenance by any other State of any such national primary or secondary ambient air quality standard, (II) interfere with efforts by any other State under part C to prevent significant deterioration of air quality or to protect visibility, or (III) contribute to air pollution which may reasonably be anticipated to endanger public health or welfare in any other State, and (ii) insuring compliance with the requirements of section 126, relating to interstate pollution abatement;".

(b)(1) Section 126(a) of such Act is amended to read as follows:

"(a) Each applicable implementation plan shall—

"(1) require each major proposed new (or modified) source—

"(A) subject to part C (relating to significant deterioration of air quality), or

"(B) which may significantly contribute to levels of air pollution in violation of section 110(a)(2)(E)(i) in any air quality region outside the State in which such source intends to locate (or make such modification),

to provide written notice to all nearby States the air pollution levels of which may be affected by such source at least sixty days prior to the date on which opportunity for public comment on the construction or modification permit commences, and

"(2) identify all major existing stationary sources, and areas of origin of emissions from all sources, which may have the impact described in paragraph (1) with respect to new or modified sources and provide notice to all nearby States of the identity and location of, and the level of pollutants emitted from, such sources and areas not later than July 1, 1982.".

(2) Section 126(b) of such Act is amended to read as follows:

"(b) Any State or political subdivision may petition the Administrator for a finding that any source or sources emit or would emit any air pollutant in violation of the prohibition of section 110(a)(2)(E)(i). Within one hundred and twenty days after receipt of any petition under this subsection, during which time a public hearing shall be held, the Administrator shall make such a finding or deny the petition.".

(3) Section 126 of such Act is amended by redesignating subsection (c) as subsection (e) and inserting after subsection (b) the following new subsections:

"(c) In considering petitions filed pursuant to subsection (b), the Administrator may not require the petitioner to rely solely on modeling or other methodologies previously approved by the Administrator for estimating interstate air pollution, but shall also consider—

"(1) the total loadings of any pollutant emitted from sources in the affected air quality control regions in each State subject to the petition,

"(2) reasonable estimates of the contribution to air quality problems in the petitioning State that come from sources outside the State,

"(3) the prevailing winds and other meteorological factors affecting the transport of any pollutant between the affected air quality control regions,

"(4) the comparative economic impact, including, but not limited to, the impact on jobs and the potential for economic growth, in affected air quality control regions in each State subject to the petition, of making such a finding or denying such petition, and

"(5) such other factors as the Administrator may establish by regulation.

"(d) If, within one hundred and twenty days after receipt of any petition under subsection (b), the Administrator has not made a ruling on such petition, the petitioning State may apply for an order in accordance with section 304(a)(2) directing the Administrator to act, without regard to the sixty-day notice requirement of section 304(b)(2). The court, on finding that the Administrator has failed to act within one hundred and twenty days after receipt of such petition, shall issue such order, shall award costs to the petitioning State as authorized under section 304(d), and shall assess a civil penalty in the amount of $100,000 against the United States, to be paid to the petitioning State.".

(c) Section 110(a)(4) of such Act is amended by striking out "and" before "(B)" and by inserting before the period at the end thereof the following: ", and (C) provide an opportunity for public comment, to extend for at least sixty days, prior to issuance of a permit to commence construction or modification".

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